PRODUCT ENGINEERING

GEORGE F. NORDENHOLT, *Editor*

Scrap Separation Pays Dividends

SHEER NECESSITY is compelling standardization and simplification in many materials and methods. The "preferred steels," as recommended by the American Iron and Steel Institute and now being further simplified and reduced in number, will undoubtedly contribute somewhat to a greater tonnage of steel production. Unfortunately, on that basis alone, the benefit of such standardization to the design engineer's company will be indirect and unmeasurable. Many designers might feel that there is little incentive to minimize the number of different alloy steels listed in their bills of materials. But now another factor has entered into the picture which will make it directly profitable to standardize on the fewest number of different alloy steels.

Most of the alloying metals used in steels have become scarce. The total supply of nickel is not much more than is required for nickel-steel armor plate, gun forgings, airplane engines and other armaments. Chromium, vanadium and tungsten are about equally scarce. If the alloying metals contained in the cuttings from machining operations were to be reclaimed, much would be gained. For example, in the manufacture of finned cylinders for air-cooled engines the scrap is much more than the weight of the finished cylinder.

Recognizing the savings that can be made, the Office of Production Management has devised a plan whereby the alloying metals will be reclaimed and the manufacturer will make a profit. All manufacturers are urged to cooperate. The plan is simple. The turnings of the different alloys are kept separate; the manufacturer then sells the different alloy scrap separately and receives a bonus or premium in proportion to the percent of nickel, chromium, or other alloy that is in the scrap. If he also briquettes his turnings, he receives an additional premium of ten dollars per ton. For example, the total premium for 3 percent nickel steel turnings briquetted is $22 per ton above the scrap price for ordinary carbon steel or mixed turnings. Even a medium-size plant will find it profitable to segregate scrap.

Obviously, the cost of keeping alloy steel scrap segregated will be less when fewer different alloys are being machined. The seventy-five different alloy classifications listed by O.P.M. can be reduced to a small fraction of that number by careful selection in the engineering department. Many designers will find it feasible and more economical to get along with only a few different alloy steels where they formerly used many.

A conservative average figure is 30 percent machined off scrap in the manufacture of a part. If all scrap turnings were segregated and returned to the steel mills, it would mean about 40 percent more alloy steel available for the same amount of virgin alloying metals. Not only would this contribute greatly to relieving the shortage in alloy steels but it would also show a handsome profit to the companies that get the premiums on their segregated scrap. One manufacturer has estimated an annual profit of $12,000 over and above what he receives for mixed scrap plus his cost of keeping the scrap separated.

All design engineers are urged to foster this O.P.M. alloy reclamation plan and to bring it to the attention of their management as both a patriotic duty and a profitable procedure.

ROLLS-ROYCE ENGINE

Adapted to U. S. Production by Packard Engineers

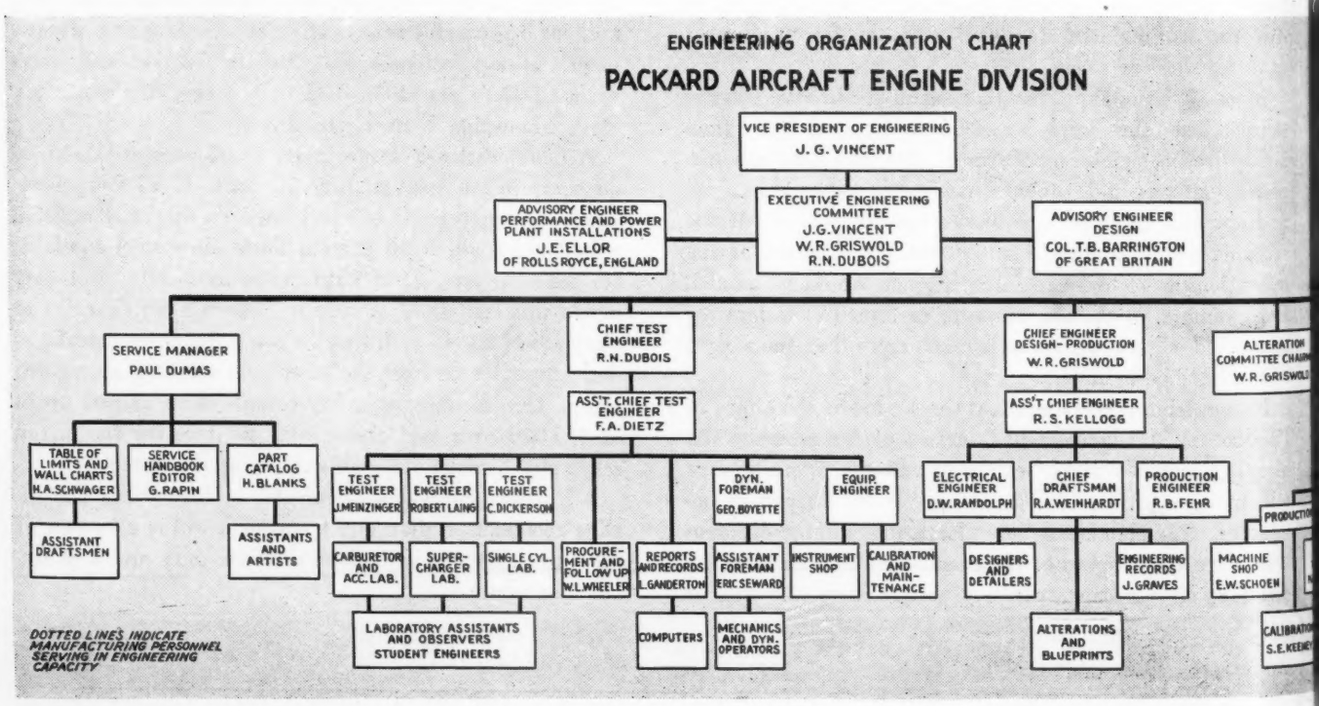
LATE LAST FALL there arrived at the Packard Motor Car Company a bundle from Britain, sealed and bonded. In this bundle were more than 2,500 detailed engineering drawings and specifications of the design of the latest Rolls-Royce engine: the Merlin XXVIII—1,300 hp., the 1,450 lb. power plant of the Hurricanes and Spitfires that maintain air supremacy over England. A production model of the engine arrived at about the same time as the drawings. With this idea and information Packard was to fulfill its contract to build on a mass-production basis Merlin XXVIII engines for Great Britain and the U. S. Army with the stipulation that no changes in design or physical changes affecting interchangeability were to be made.

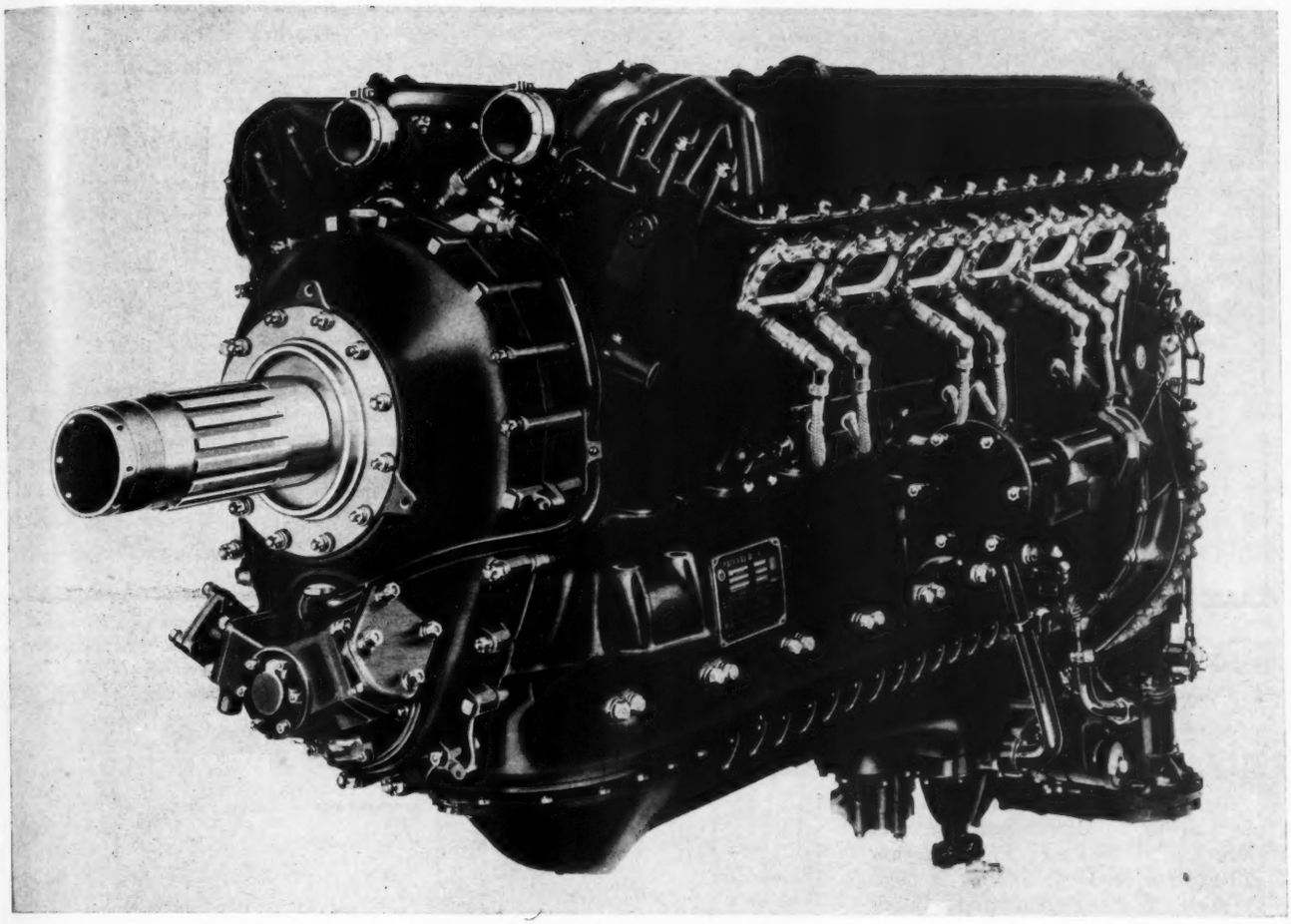
Before even the plans for production could be started, it was necessary that Packard engineers make new drawings to conform to American drafting room standards and practices without affecting design or interchangeability of parts as manufactured in England. Complete shop notes had to be placed on each drawing. Not until the final approved American drawing of a part was completed was it possible to design the patterns, dies, jigs, or fixtures required for manufacturing. Not until all the parts had been studied and analyzed was it possible to go ahead with the production study to determine the machine tools required, the shop arrangement and the size of plant required. Along with this, two buildings had to be designed and erected; machine tools ordered, procured and set up; patterns, dies, jigs, tools and fixtures and gages built. Packard can well be proud of the job it did. In less than ten months from the receipt of the drawings and model engine, two new Packard plants began pouring out duplicates of the Rolls-Royce Merlin XXVIII engines and by December 1941 mass production will be in full swing.

The first step was to organize quickly and efficiently an engineering department. Col. J. G. Vincent, Vice-president of Engineering at Packard was immediately appointed to head this new aircraft engine engineering division and was assigned the task of building a complete organization around key men of Packard's engineering department. As organized, by Col. Vincent, the active coordination of the work of the Packard Aircraft Engine Division engineering department centers in an executive engineering committee consisting of Col. J. G. Vincent, W. R. Griswold, also chief engineer in charge of coordinating design and production and R. N. DuBois also chief test engineer of Packard. This executive engineering committee consults with Col. T. B. Barrington of England who advises on matters relating to possible design modifications that might be deemed desirable, and with Mr. J. E. Ellor of the Rolls-Royce Company of England on problems relating to engineering performance and power plant installation.

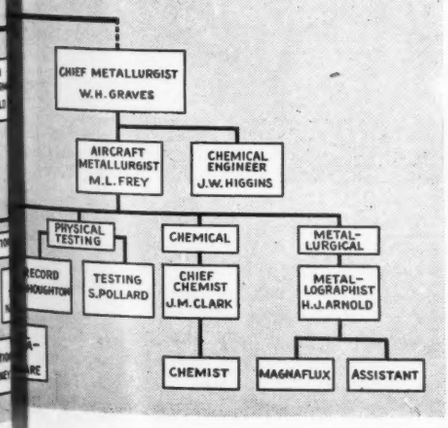
As shown by the accompanying organization chart, service manager Paul Dumas, and chief metallurgist W. H. Graves tie in with the executive engineering committee. W. H. Graves has charge of all the metallurgical work involved. It was his responsibility to specify American materials that conformed to the English materials in the sample engine.

It was simple enough to redraw all the English drawings which were in first angle projection to conform to the American practice of third angle projection. But there were a number of other differences between the English





Rolls-Royce Merlin XXVIII as being built by Packard is the same in all details as the design called for by the English drawings. But it was no small job to revamp the English first-angle projection drawings, put on the information required for American practice, and to determine the S.A.E. or special alloys to be used. Another major problem was to specify tolerances completely so as to minimize hand fitting

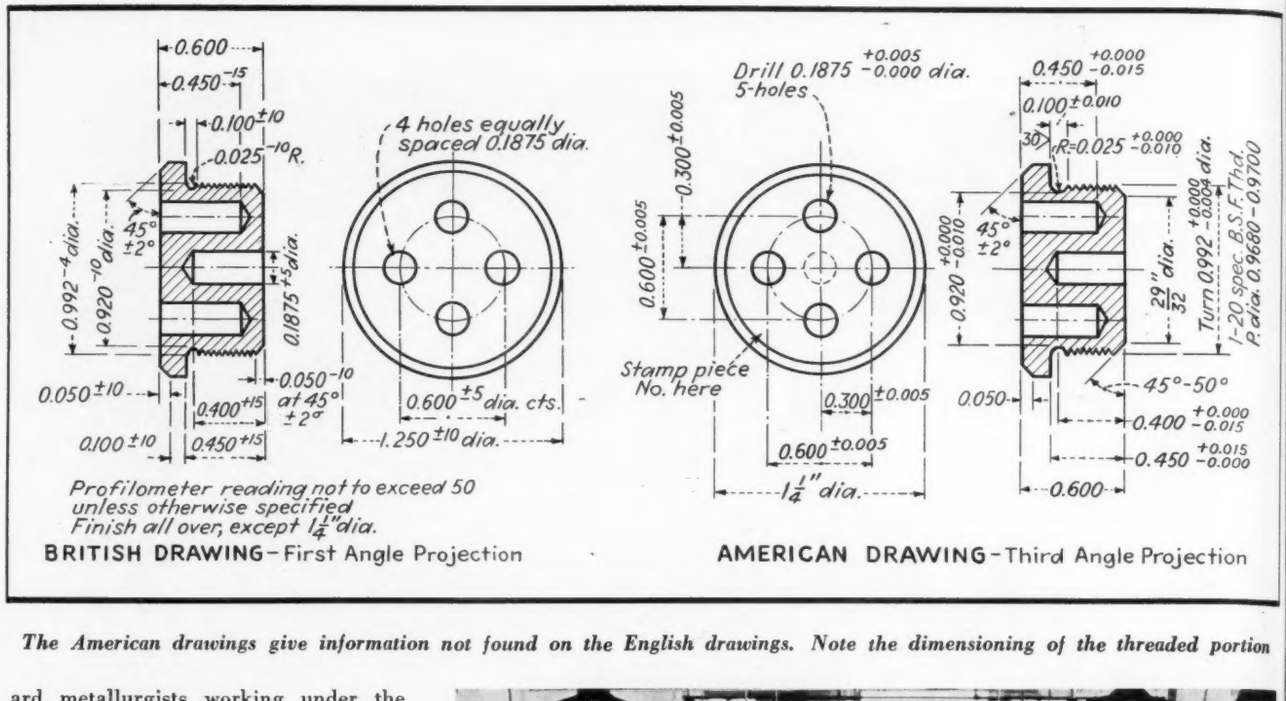


drawings and American practice that were not so easy to reconcile. Although the English drawings specified tolerances in most cases but there were also many general notations such as, "This surface must be square with bore," or, "These surfaces must be parallel," without any tolerances being specified. The drawings also gave no indication as to the method of surface finishing to be used nor was the quality of the surface finish specified in any manner.

Another and even more time consuming problem was caused by the difference between English and American practice in the thread forms used. In view of the necessity of maintaining complete interchangeability between American and British made engines, it was necessary to conform to the British practice in the thread forms used. The problem was further complicated by the fact that the British Rolls-Royce engine uses three different types of thread, namely: British Association, British Standard Form Whitworth and metric. To complicate matters still further, some of the threads on the English Rolls-Royce engine are modified forms of these three types. This is no criticism of the English design but it does indicate the great differences between American and English standards and practices.

A study of the drawings also revealed that the English design was predicated on a considerable amount of handwork or handfitting on the assembly line. The problem for the Packard engineers to solve was how to redesign some of the details in order to avoid such handfitting and yet not affect complete interchangeability of parts. It is significant that although the Packard engineers were not able to completely eliminate handwork on the assembly line, assembly time was reduced considerably through the elimination of about two-thirds of the handfitting required on the original British design.

The final problem was to specify commercially obtainable American alloys for the various parts. The standard alloys in the English engine naturally differed from American S.A.E. alloys. It was necessary for the Packard engineers to analyze chemically the materials used in the sample Rolls-Royce engine. This was done by Pack-

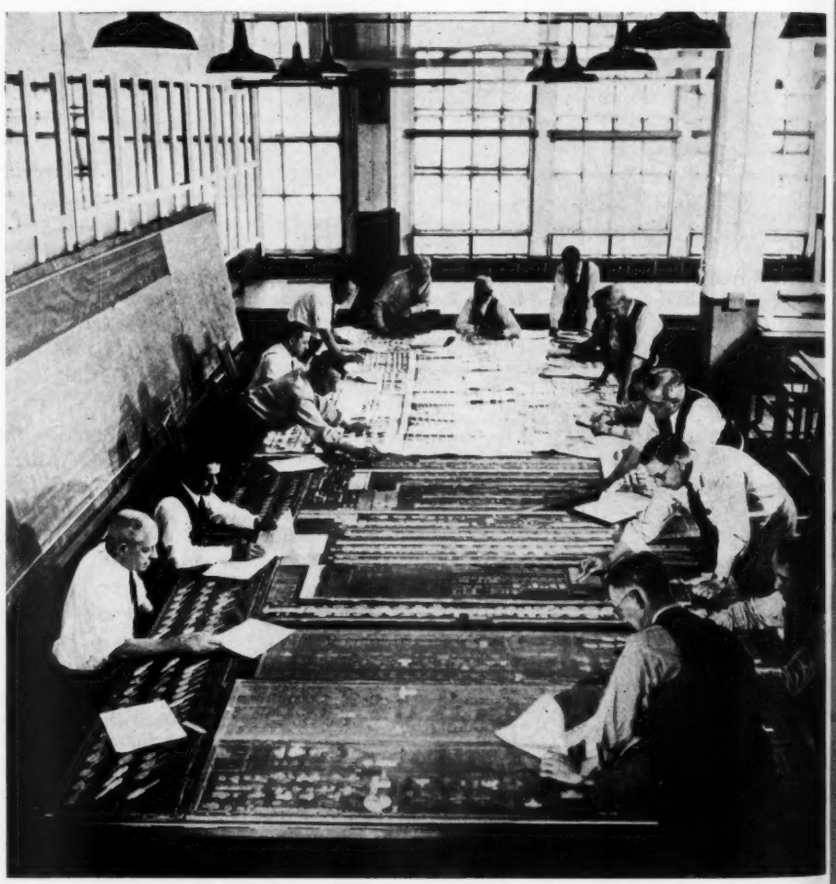


The American drawings give information not found on the English drawings. Note the dimensioning of the threaded portion

ard metallurgists working under the direction of the chief metallurgist, W. H. Graves. After the complete analysis had been made, an equivalent S.A.E. or special steel and its heat-treating schedule had to be determined. Tests of alloys selected by Packard metallurgists had to show physicals at least as good as those of the English alloys used. Before an alloy and its heat-treatment was adopted, Dr. Lessels, advisory metallurgist for Rolls-Royce in England, was consulted.

It must not be assumed that there was any fault to find with the English design or the manufacturing methods they specified. To the contrary, Rolls-Royce has been developing designs of liquid-cooled airplane engines since the days of World War I. Naturally over the span of 25 years Rolls-Royce engineers have gradually perfected the designs of their engines. The present model, Merlin XXVIII, was first produced in England in April 1941. It is a 60 deg., 12-cylinder engine with a straight spur propeller reduction gear and a two-speed centrifugal supercharger. The supercharger has semi-centrifugal friction drive clutches and an oil-operated system for gear selection. Automatic metering of the 100 octane fuel used is obtained through a specially designed Bendix floatless injection type carburetor. The ignition system includes dual magnetos, radio-shielded wiring harness and 14 mm. spark plugs.

In order to get into manufacturing with all possible speed, the engineering division set up a schedule wherein parts that required the maximum for manufacturing preparation were redrawn first. For example, forgings and castings were classified as "long time" parts. Parts that could be machined out of stock were classified as "less urgent." The "long time" parts were studied first. Every detailed drawing had to be redrawn if for no other reason than to change the drawings from first angle to



When the Packard engineers started their work on the English drawings they had to get along as best they could in the cramped quarters of the only drafting room available, as shown in the illustration above. On the facing page is shown the spacious and well-lighted engineering department in the new Packard Rolls-Royce building

third angle projection. When the engineer was given the detailed drawing to revamp, he was also given the actual part. In developing the new drawing the engineer worked closely with the men from the Packard production departments. Conforming to American practice, as much production data as feasible were put on each drawing. Also because the English drawings do not specify production methods used or the quality of the surface finish, it was necessary to determine the character of the surface finish of each of the parts as taken from the sample engine. The surfaces in question were carefully explored with a profilometer and the surface finish specified accordingly on the American drawing. The proper instructions were then placed on the new drawing as to production methods to be used in order that the surface finish on the sample part would be duplicated.

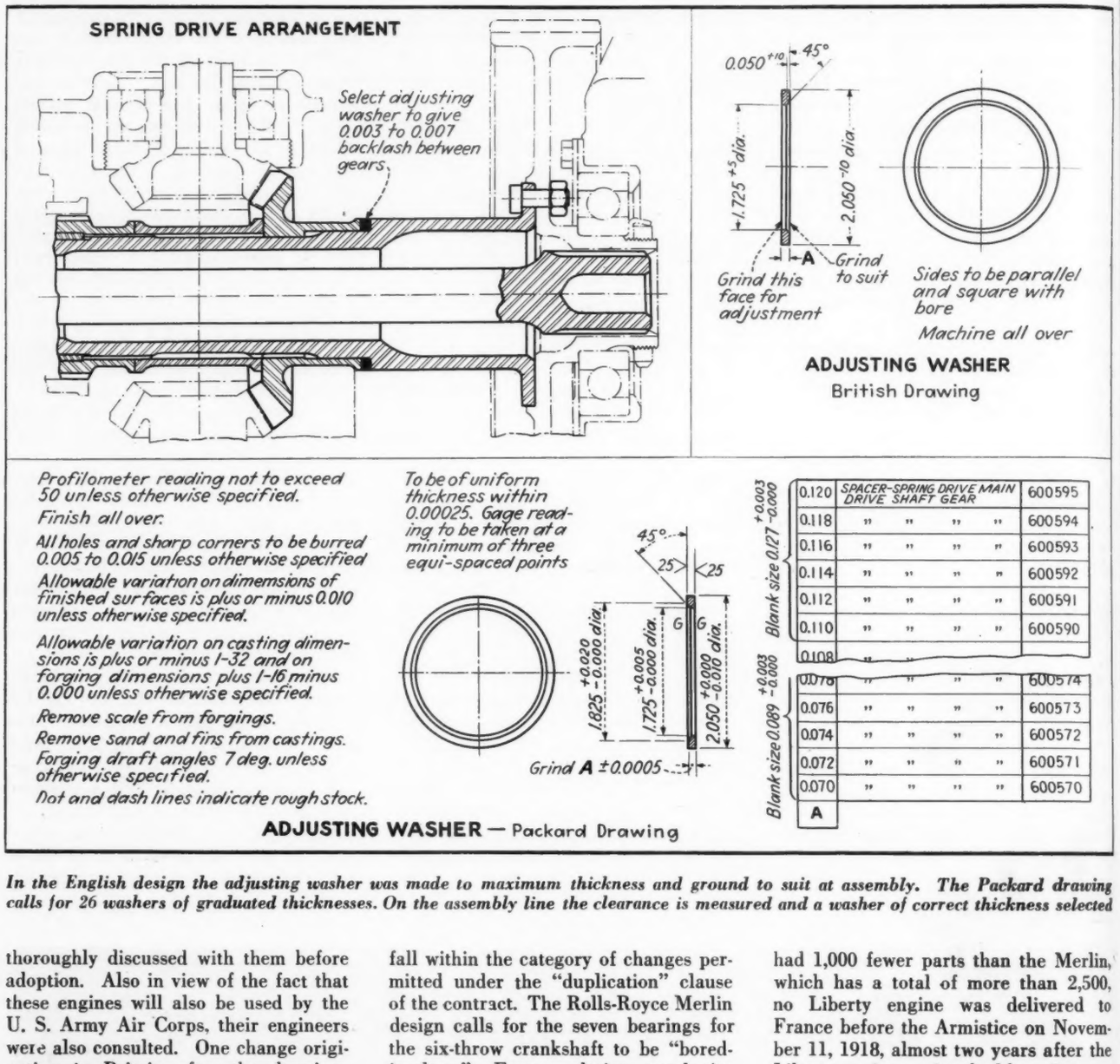
The task of specifying the thread forms on the American drawings was a painstaking one, complicated by the fact that many of the bolts, nuts and studs were to be furnished by sub-contractors. It was necessary to specify the taps and the go and no-go gages. To this end, a large chart in blueprint form about four feet wide and eight feet long was made. On this chart were listed the thread sizes, screw sizes, nut sizes, fit and pitch diameter, tap sizes, go and no-go gage dimensions for all of the different sizes and thread forms used. This list included the British Association, British Standard Form, the metric, the Whitworth and modified Whitworth threads and the straight pipe threads. The work of making this chart was under the direct supervision of chief engineer Griswold and his assistant R. S. Kellogg.

A study of the British drawings seemed to indicate that often the British practice is to make the parts to close dimension and then fit by hand methods to the sizes necessary. Apparently this method of assembly is used for 20 or more different parts on the English Rolls-Royce engine. However, it is a method of assembly that is not suitable for the American production practice. For example, the British practice is to make spacing washers oversize on their thickness. In the assembly the spacing washer face is ground down until the proper space or clearance is obtained. Not only is this a time consuming operation which holds up the assembly line but it also requires that skilled labor be used because a man on the assembly line must do the grinding. To avoid this situation, the Packard engineers decided to detail the drawing for such spacers to call for 25 standard spacers varying in thickness by steps of 0.002 in. On the assembly line it is then merely a matter of selecting the thickness of spacer which gives the desired clearance. This procedure makes possible quicker assembly, avoids the necessity of skilled labor and no time is lost in additional machining operations.

In the accompanying illustration is shown the design of adjusting washer as designed by the English engineers. This particular washer is interposed between the extended hub of a gear and a ball bearing inner race in order to adjust the backlash of the gear. It will be noticed that the English drawing has a notation "grind this face for adjustment" and also carries the notation, "grind to suit." The Packard drawing specifies the thickness of the washer as an *A* dimension and calls for spacers of 26 thicknesses ranging from 0.070 to 0.120 in. in steps of 0.002 in. It will also be noticed that the Packard drawing indicates the profilometer reading of the surface on the face of the spacer.

It was also found necessary to check the English drawings against changes that might have been made after the drawings had been sent to Packard. For example, when the foundry drawings were compared with castings on the sample engine, it was found that the wall thicknesses of the rough casting were 1/16 to ⅛ in. greater than the thickness indicated on the English drawings. When this matter was called to the attention of the English representatives, it was explained that the British departure from the drawings was often dictated by experience or production changes which in these instances resulted in an increase of wall thickness and of fillet radii on the castings by 1/16 to ⅛ in. With a number of suppliers furnishing the castings for Packard, it was necessary to have the casting drawings accurate and the drawings had to be changed accordingly.

Wherever slight changes were necessary, the problem was taken up in detail with the resident British engineers and


SPRING DRIVE ARRANGEMENT
Select adjusting washer to give 0.003 to 0.007 backlash between gears
0.050 +.10
45°
1.725 +.5 dia.
2.050 -.10 dia.
A
Grind to suit
Grind this face for adjustment
Sides to be parallel and square with bore
Machine all over
ADJUSTING WASHER
British Drawing
Profilometer reading not to exceed 50 unless otherwise specified.
Finish all over.
All holes and sharp corners to be burred 0.005 to 0.015 unless otherwise specified
Allowable variation on dimensions of finished surfaces is plus or minus 0.010 unless otherwise specified.
Allowable variation on casting dimensions is plus or minus 1-32 and on forging dimensions plus 1-16 minus 0.000 unless otherwise specified.
Remove scale from forgings.
Remove sand and fins from castings.
Forging draft angles 7 deg. unless otherwise specified.
Dot and dash lines indicate rough stock.
To be of uniform thickness within 0.00025. Gage reading to be taken at a minimum of three equi-spaced points
45°
25
25
G
G
1.825 +0.020 -0.000 dia.
1.725 +0.005 -0.000 dia.
2.050 +0.000 -0.010 dia.
Grind A ±0.0005
Blank size 0.127 +0.003 -0.000
Blank size 0.089 +0.003 -0.000
0.120 SPACER-SPRING DRIVE MAIN DRIVE SHAFT GEAR 600595
0.118 " " " " 600594
0.116 " " " " 600593
0.114 " " " " 600592
0.112 " " " " 600591
0.110 " " " " 600590
0.108 " " " "
0.078 " " " " 600574
0.076 " " " " 600573
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0.072 " " " " 600571
0.070 " " " " 600570
A
ADJUSTING WASHER — Packard Drawing

In the English design the adjusting washer was made to maximum thickness and ground to suit at assembly. The Packard drawing calls for 26 washers of graduated thicknesses. On the assembly line the clearance is measured and a washer of correct thickness selected

thoroughly discussed with them before adoption. Also in view of the fact that these engines will also be used by the U. S. Army Air Corps, their engineers were also consulted. One change originating in Britain after the drawings were sent to Packard, was the use of a two-piece engine cylinder assembly instead of the one-piece design in former Merlins. Because it was much easier for the factory to make this assembly in two pieces instead of one, this change was highly desirable. It is possible that a number of other changes of that nature would have further simplified the manufacturing problems, but it was felt that the necessity for interchangeability and the high requirements of these engines for planes operating in combat service with the throttle wide open most of the time, made it impossible to adopt major revisions or simplifications as there was no time available to make the thorough tests that would have been required.

However, the Packard engineers did request one major change which did not fall within the category of changes permitted under the "duplication" clause of the contract. The Rolls-Royce Merlin design calls for the seven bearings for the six-throw crankshaft to be "bored-in-place." From a design standpoint this method of aligning bearings is perfectly satisfactory but it not only requires much more skilled labor and time but also causes interruption in the assembly line. The Packard engineers recommended the use of precision steel-backed bearings instead of "bored-in-place" bearings. Although the precision bearings are considerably higher in first cost, they permit much quicker assembly and can even be used in the British built engines when necessary to do so.

A fair idea of the speed efficiency and effectiveness with which Packard engineers and production men worked to get the Rolls-Royce Merlin into production can be gained by a comparison with the progress made in the manufacture of Liberty engines for World War I. Although the Liberty engine had 1,000 fewer parts than the Merlin, which has a total of more than 2,500, no Liberty engine was delivered to France before the Armistice on November 11, 1918, almost two years after the Liberty engine project had been inaugurated. Of course, the Liberty engine was an entirely new development whereas in the case of the Rolls-Royce Merlin there were all the advantages of 25 years' engineering development. But this does not detract from the fact that in less than one year, Packard engineers revamped completely more than 2,500 detailed drawings and Packard production men built two new plants, assembled and installed all the production machinery, and got production into full swing.

Actual delivery of the first engines was made on August 2, one to Britain and one to the U. S. Army. The event was celebrated by a world-wide short-wave broadcast, during which an R.A.F. pilot "somewhere in England" gave the command that set engine No. 1 roaring on the test block.

ACRYLIC PLASTICS

Their Applications and Light Piping Characteristics

D. S. FREDERICK
Plastics Sales Manager, Rohm & Haas Company

MANY DESIGNERS know how extensively cast acrylic sheets are being used by the aircraft industry for transparent cockpit inclosures, blisters and observation turrets. These sheets are actually clearer than glass, a great deal stronger and less than half as heavy as glass, and they can be cut with ordinary saws, machined, carved and drilled with the usual metal working equipment and cemented in strong transparent joints.

The use of acrylic sheets, which have high impact strength, to replace glass over the dials of gages and other indicators where glass would be a hazard because of its fragility, has become widespread. If desired, the installation can be made waterproof by taking advantage of the fact that being thermoplastic, the acrylic resin material softens when heated and can be easily formed to shape. When cooled, it will retain this shape until it is reheated when, because of its so-called elastic memory, it will resume its flat sheet form. To make a tight, waterproof joint, therefore, the sheet is heated and formed to the shape of a dome, snapped into position in the mounting ring of the gage, and heated again, upon which the sheet tends to flatten, forming a tight, waterproof joint. Waterproof acrylic resin cements may also be used for this purpose, alone or in combination with gaskets.

Because acrylic resins are thermoplastic, the sheets can be made readily into curved inspection windows in all types of machinery. After heating in an ordinary oven and then shaping over a wooden form—to fit any strategic part of a machine, the sheet can be mounted securely and simply.

Transparency can also be a big safety advantage. In the G & W Electric Company's subway switch, for example, an acrylic resin sheet permits the operator to make sure the switch is open before working on the switch. Transparency, as well as the need for curved sections also dictated the use of this material in the re-styled Tel Autograph telescriber, the strength of the acrylic sheet reducing breakage both in assembly and in service.

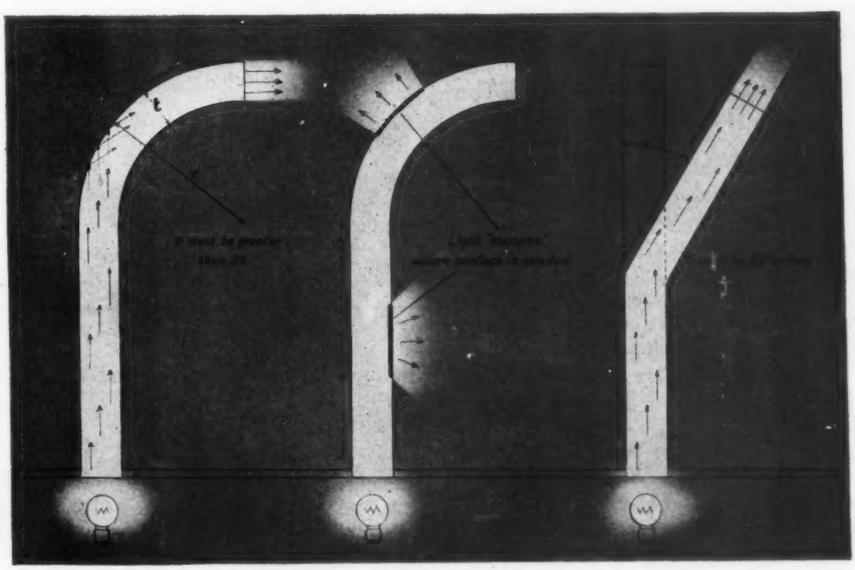
In industrial applications, the acrylics are also useful because of their resistance to most chemicals, to alkalis, to non-oxidizing acids, to oils, to solutions of inorganic salts, and to almost any chemicals except organic solvents and lacquer thinners. Because particles of abrasives bounce from its resilient surface, causing only minor damage, acrylic resin sheets can often outlast glass many times over on grindstone guards and in applications where scratching is a serious factor. If the minor scratches eventually obscure vision through the sheet, they can be polished out on soft linen buffing wheels using fine polishing compounds.

When a large number of any one size and shape of gage glass or inspection window is required, further advantages can be obtained by molding the piece rather than fabricating it from sheet. In the molding operation, particles of granules of the resin are heated and put under pressure until they soften and fuse into moldings identical with the mold in shape. Molding eliminates almost all of the ordinary fabricating operations and can also eliminate costly assembly operations and complicated mounting devices.

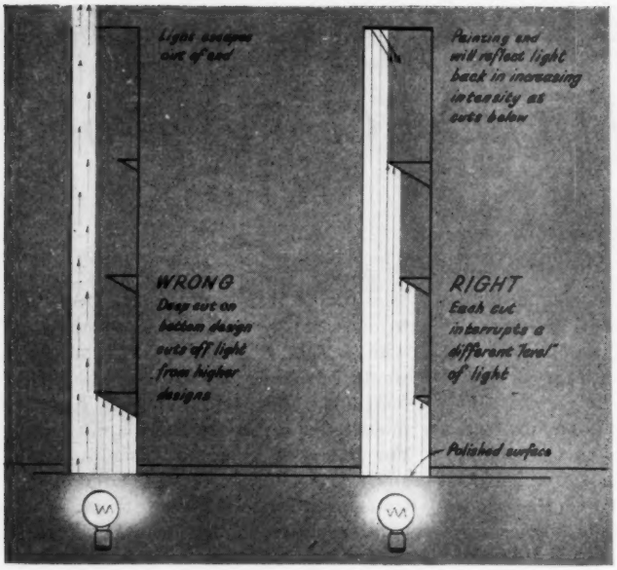
Take the case of the General Electric relay cover as an example. Before the advent of acrylics, a glass to cover the face of the relay would have been cut to size and mounted in a metal bezel with a rubber gasket which, in turn, would have been screwed to the relay housing. Instead, General Electric molded a cover in one transparent piece. For the sake of appearances, a black rim was painted around the edge of the transparent moldings but there is no other assembly operation. The breakage, of course, both in manufacturing and in service, was materially reduced; and possibly most important, it gave the relay an extra selling advantage.

A large gage manufacturer has ingeniously molded a thread onto his gage cover which enables him to screw his durable, crystal clear molding directly into the housing. It is also possible to mold a flange or rim which can materially simplify mounting without sacrifice of strength.

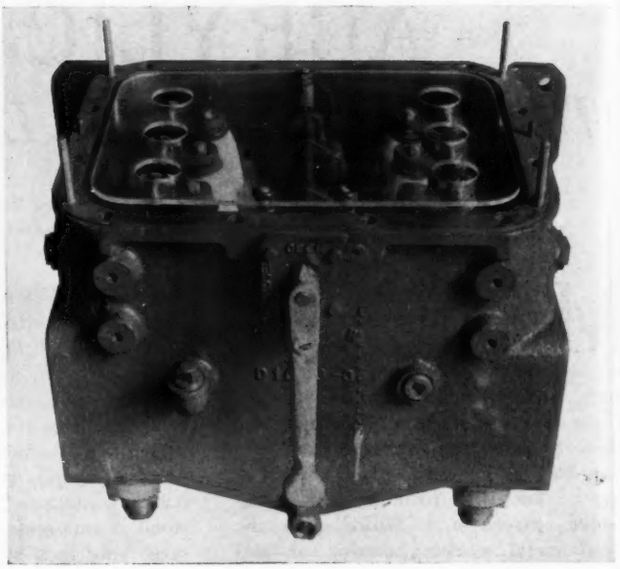
These simplified mounting arrangements have also been used by leading manufacturers of radios and automobiles to whom assembly costs are vitally important. But they have also used an extra advantage of acrylics—the ability to pipe light from edge to edge with remarkable efficiency. A light bulb placed at the edge of these moldings provides even, glare-free illu-



Here are shown the limits of bend angle and curvature radius for cast acrylic parts that are to conduct or pipe light


Light escapes out of end
Painting and will reflect light back in increasing intensity as cuts below
WRONG
Deep cut on bottom design cuts off light from higher designs
RIGHT
Each cut interrupts a different "coral" of light
Polished surface

Indicating the right and wrong way of designing a molding so as to get uniform intensity of light over all the markings



Cast acrylic covers for switch boxes have the advantage that the position of the switch can be seen without opening box

mination of every marking molded into the piece. In the Philco automobile radio, compact design prevented the installation of the bulb directly at the edge of the dial, but a curved Crystalite molding piped the light around the corner.

The accompanying diagram explains this light piping and also reveals its limitations:

1. Acrylic sheets or moldings will pipe light only around a curve, the radius of which is greater than three times the thickness of the molding.

2. They will pipe light through a sheet bent to an angle of 42 deg. or less.

3. The markings in the molding must be arranged properly if an equal intensity of light is to reach all of them.

Besides these optical limitations, there are several practical ones. The first is that it is difficult to concentrate enough illumination into the edge of any sheet or molding to permit comfortable reading of printed matter under the light transmitted at the other edge. Second, the accompanying diagrams assume an optically perfect surface free of dust and even minor imperfections. While the surfaces of cast acrylic sheets and properly molded Crystalite can closely approximate this perfection, they do fall short of it. And dust we have always with us.

Despite these limitations, a small light bulb with only the simplest kind of reflector provides satisfactory illumination for a dial six to eight inches long, even though that dial may be bent to a fairly sharp angle. Most of the molded dials used on 1941 cars are more than a foot long and are lighted by only two bulbs, one at each end of the dial.

While most of the foregoing discussions have centered on dials molded from powder, most of the considerations also apply to dials, nameplates and other markings stamped into cast acrylic resin sheets. Before stamping or punching the sheet, it is necessary to warm the sheet in hot water or on a steam table. By heating the sheets to higher temperatures and using greater pressures, it is possible to emboss the surfaces with deep designs, rosettes and scrolls to obtain decorative effects. Stamping dies are usually less expensive than molds and stamping is, therefore, used when quantities are small, or when the size of the piece involved is larger than molding facilities available can accommodate.

In the plastics industry, countless im-

Physical Properties of Acrylic Resins

(The figures shown in the following table are calculated from standard A.S.T.M. tests on standard pieces at 30 deg. C. and are subject to variation with changes of molding conditions or shapes of pieces.)

Powder	Compression	Injection
Molding Temperatures	300 to 360 deg. F.	325 to 450 deg. F.
Molding Pressure	2,000–4,000 lb./sq.in.	Medium to high
Compressive Ratio	1.7 to 2.0	2 to 2.4
Molded		
Refractive Index	1.49	1.49
Light Transmission	90 to 92 percent	90 to 92 percent
Specific Gravity	1.19	1.18
Specific Volume	23.2 cu.in./lb.	23.5 cu.in./lb.
Tensile Strength	4,000–6,000 lb./sq.in.	
Compressive Strength	10,000–15,000 lb./sq.in.	
Flexural Strength	9,000–12,000 lb./sq.in.	10,000–11,000 lb./sq.in.
Impact Strength (Charpy unnotched bar ½ in. sq.)	1 to 2 ft.lb.	3 to 4 ft.lb.
Mold Shrinkage (Cold mold to cold piece)	0.001 to 0.005 in./in.	0.004 to 0.006 in./in.
Shrinkage after Molding (30 days at 140 deg. F.)	0.001 in.–0.006 in./in.	0.006 to 0.015 in./in.
Thermal Expansion	$8x10^{-5}$/deg. C. (Approx.)	
Specific Heat	0.4 cal./deg. C./gm.	0.4 cal./deg. C./gm.
Water Absorption by Weight		
48 hr	0.4 to 0.5 percent	0.3 to 0.4 percent
Equilibrium	1.4 to 1.7 percent	1.3 to 1.5 percent
Electrical Properties	Very good	Very good
Burning Rate	Slow	Slow
Machining Properties	Excellent	Excellent
Heat Distortion Point (A.S.T.M. D-48-37)	125 to 165 deg. F.	125 to 140 deg. F.

provements in materials, equipment and molding processes are rapidly pushing back frontiers which were hitherto considered sacred. One excellent example of a large molding is a bowl-shaped part for hair driers. It is more than 13 in. in diameter and weighs slightly more than 26 ounces. It is compression molded, and, included as integral parts are a number of flanges to direct the air current when the drier is in use and to facilitate mounting in assembly. It is a piece which as recently as a year ago might well have been considered impossible.

Within the last year the plastics industry has also come to change its conception of the limitations in injection molding of thick sections. The radiator ornament on the 1941 Pontiac—a piece weighing six ounces and more than a half-inch thick in some sections—was injection molded this year for the first time.

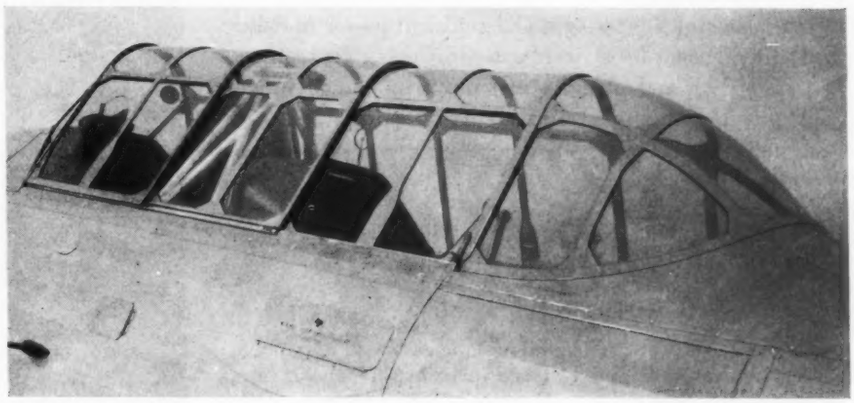
Drug stores have recently been featuring an equally impressive demonstration of heavy sections molded by injection machines. They are Pro-phy-lac-tic brushes molded by Pro-phy-lac-tic after a number of custom molders had refused to undertake the job. These brushes illustrate still another advantage of acrylics based on their crystal clarity. By the addition of small amounts of dye, delicate tints may be obtained which add immeasurably to any item where appearance is a selling factor. The permanence of the acrylics' crystal clarity through years of washing and weathering is also an important advantage obtained by the use of this material.

Designers can also look to the aircraft industry which has used cast acrylic sheets longer and more extensively than any other industry. Back in 1936, these were used in windows and occasional flat sections to replace glass or other, less stable, plastics. The light weight, high impact strength, and permanent transparency were all important. It was not long before further improved methods of installation were developed.

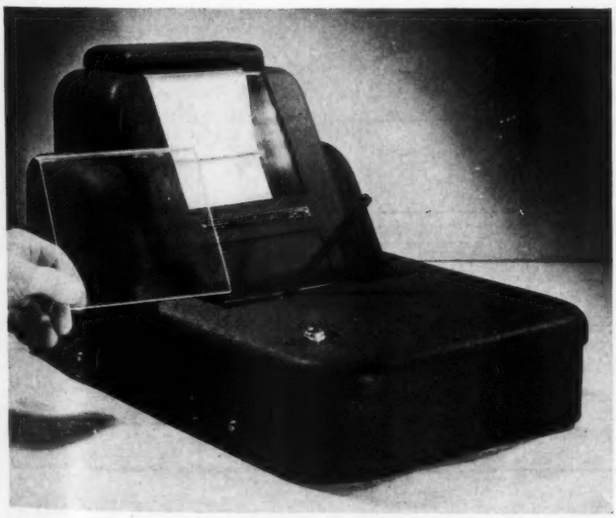
The ease in forming the sheet led to its use in landing light covers and cockpit enclosures or "green houses." Now, observation turrets and machine gun blisters are appearing on America's bombing planes and giving today's pilots the important tactical advantage of all around visibility. More recently, aircraft radio engineers have been using acrylic resins to enclose radio antennae because they found that they did not interfere with radio reception and that these plastic housings permitted the mounting of antennae several feet from the nearest metal part without loss of reception efficiency. Numerous other applications of acrylic resins in the design of aircraft are in process of development.

As is true for every material of construction, best results are obtained only when full consideration is given to all of the production methods to which the material is inherently suited. In the case of acrylic resins these include not only their easy machinability and formability but also the ease with which pieces can be "welded" together. (See P.E. March 1940 for designs of sheet mountings.)

Not every industry will demand as much of the acrylics as aircraft designers have, but many will benefit from a study of these unusual plastics. They are not miracle materials; they have their limitations; but the acrylics hold out rich rewards to the designer who recognizes all their possibilities for product improvement.



One of the first fields of general application for cast acrylics was in airplanes. Lightness, toughness and ease of application made this material ideal for windows and inclosures. The sheets can be bent readily to any desired curvature after warming



Because cast acrylic sheets are virtually unbreakable they have been preferred for many applications such as this one

Ability of acrylic resin to pipe light makes it a highly suitable material for the manufacture of illuminated dials

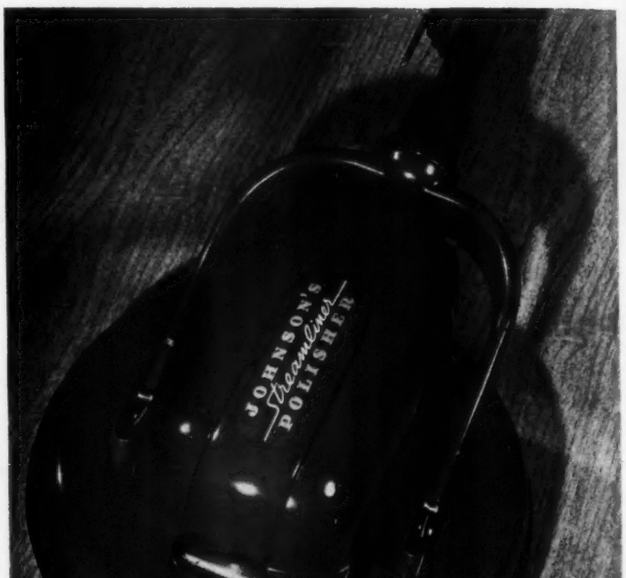
Modern Designs

Balance and Light Weight for Control

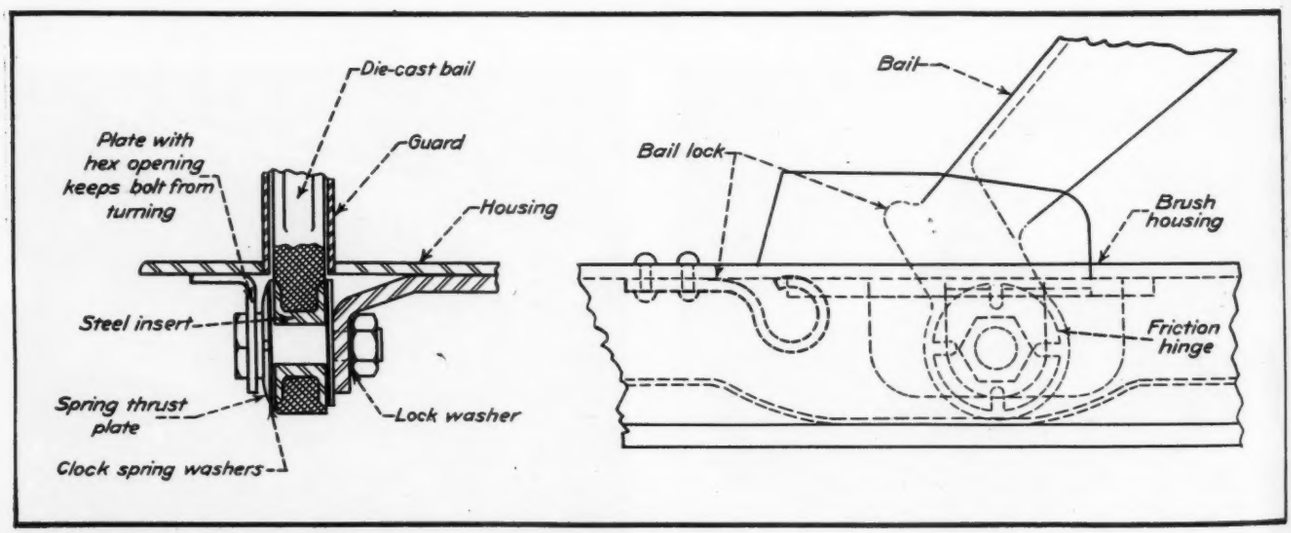
"To make a floor polisher which would guide as easily as a vacuum cleaner required a combination of proper weight balance and a floating handle which would isolate vibration and shocks from the operator," said G. A. Zimmerman, vice-president of The Dumore Company, in discussing the new Johnson Streamliner floor polisher.

"By using properly located weights, H. S. Smith and J. H. Nelson, of our engineering staff, were able to balance the effect of the rotating forces. And by isolation of the handle with rubber and with friction damping, operator fatigue was reduced.

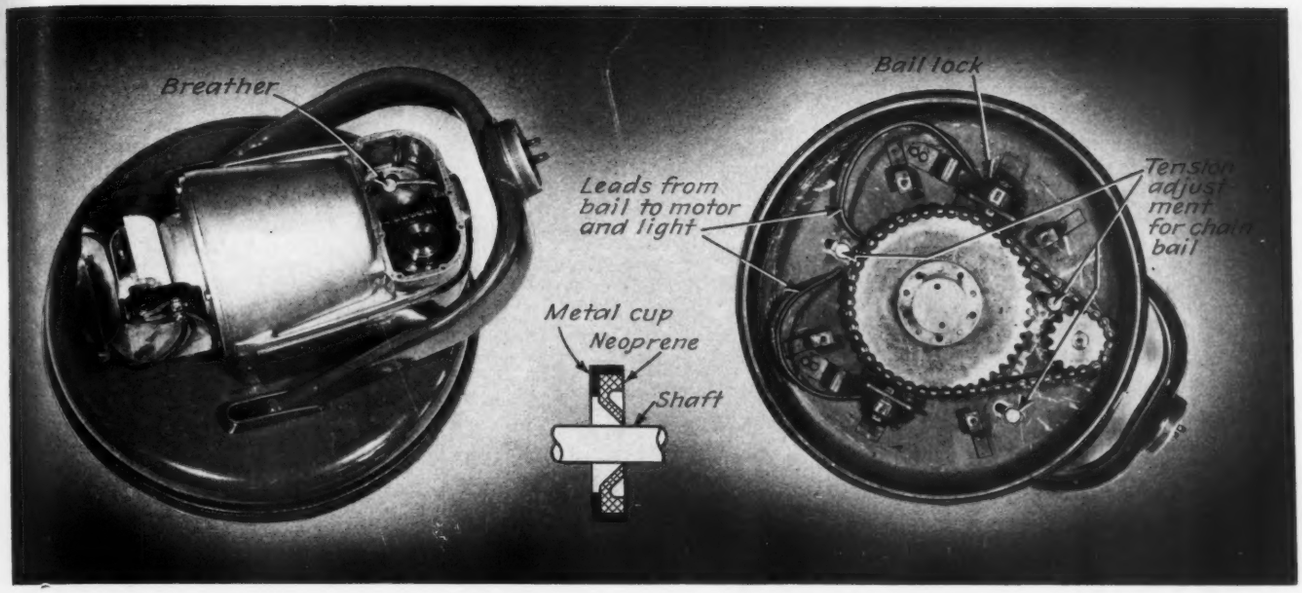
"Problems of light weight and sufficient power to drive an 11-in. diameter brush were solved by using die-castings and stampings and a high-speed universal motor which made possible a high power rating in a small space."



Tubular steel handle, aluminum die-cast bail, aluminum die-cast motor cover and stamped steel brush housing are finished in cherokee red enamel which is applied immediately after parts are polished. Leather bumper is riveted to housing.

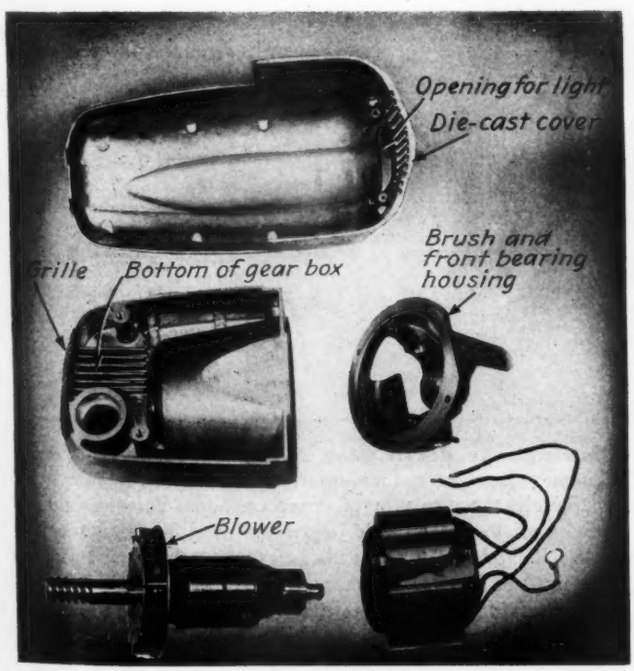


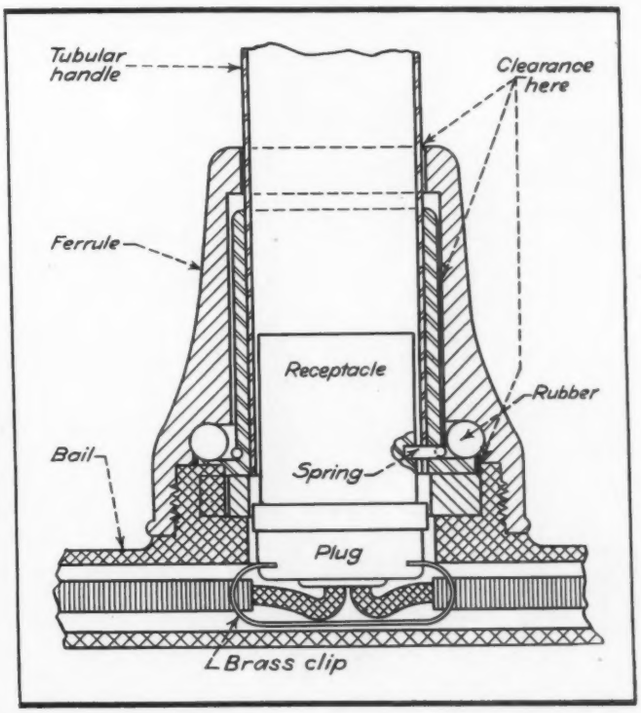
Friction type hinges join bail to polisher. Steel collar is die-cast into end of bail. Spring thrust plate acts against clock spring washer, which in turn presses against face of insert. Other side of insert bears against steel washer. Bail lock is narrow steel loop which acts against knob on bail to hold handle vertical.



Worm ground in steel motor shaft drives bronze worm-wheel on end of shaft which drives sprocket below. Breather allows for expansion of oil which heats up due to high-speed operation. Chicago Rawhide neoprene seal keeps oil from motor. Gear box is covered by neoprene gasket and steel plate, both stamped in one operation. Chain drive reduction gives brush rotation of about 76 r.p.m., motor speed being over 10,000 r.p.m. Tension on roller link chain is adjusted by three hex head bolts which pass through slots in brush housing into motor frame. Five socket head screws fasten brush holder plate to collar around the grease sealed ball bearing supported stub shaft.

Die-cast aluminum cover contains 10 percent silicon to get necessary strength in the thin section. Fins in aluminum die-cast motor housing help cool oil in the gear box, air being drawn in through the grille at the front of cover, over the armature and expelled underneath gear box and out the grille at rear. Blower is staked to armature shaft. Air is drawn in through the center of first plate and expelled over the edge of second plate. Worm on end of shaft has such a lead that oil is not pumped back against the oil seal when motor is in operation.

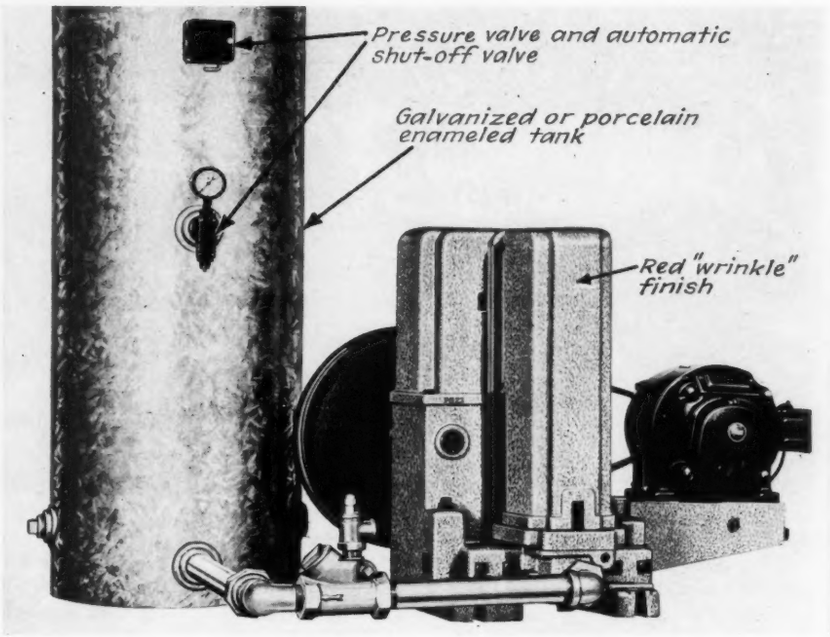


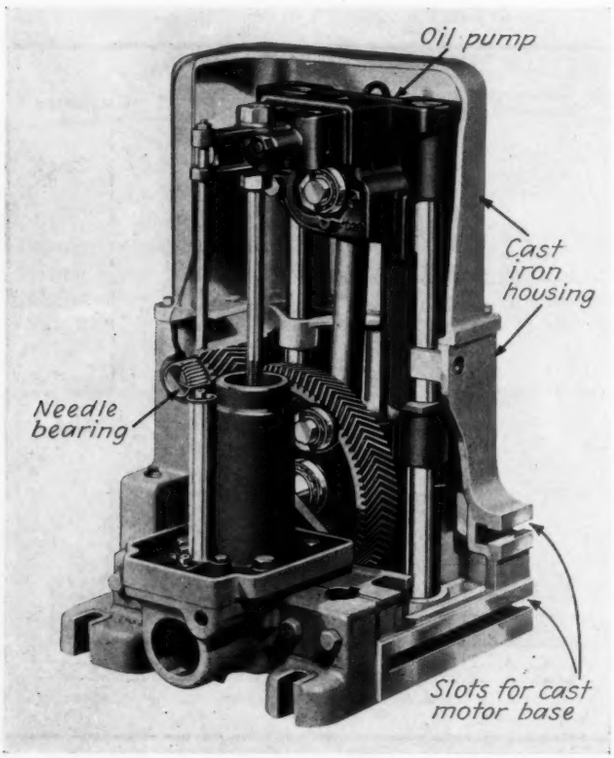


Operator fatigue is reduced by isolating handle by rubber washers. Rectangular washer takes only compression and is used to take normal pushing loads. Round washer cushions smaller pulling loads. Ferrule is machined from aluminum bar stock. Rubber washer and bushing are kept from turning by integral cast knob. Bent end of round wire spring holds receptacle handle and bushing in position. Brass clip holds plug and wire in bail. Trigger type control operates a Cutler-Hammer switch which is housed in die-cast pistol grip handle, to start and stop motor.

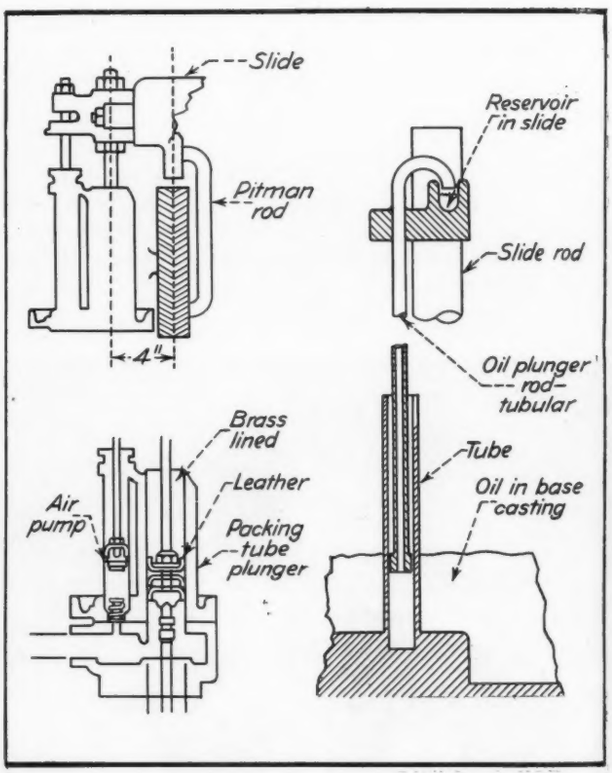
MODERN DESIGNS – Sub-Assemblies for Servicing

Discharge unit and pump bracket sub-assemblies and sectionalized castings are used in Monitor Silent Flow deep well pumps to permit easy servicing and also to permit discharge unit to be placed at any underground depth without extra equipment. Housing consists of top and bottom casting and a casting to cover discharge unit. Cast motor base fits in T-slots in housing. Cast bracket for upper end of pump rod bolts to cast slide. Quiet operation is claimed as a result of machining all moving parts to close fits and tolerances, using herringbone gear drive, equalizing upstroke and downstroke load on motor, and using cast iron inclosure.



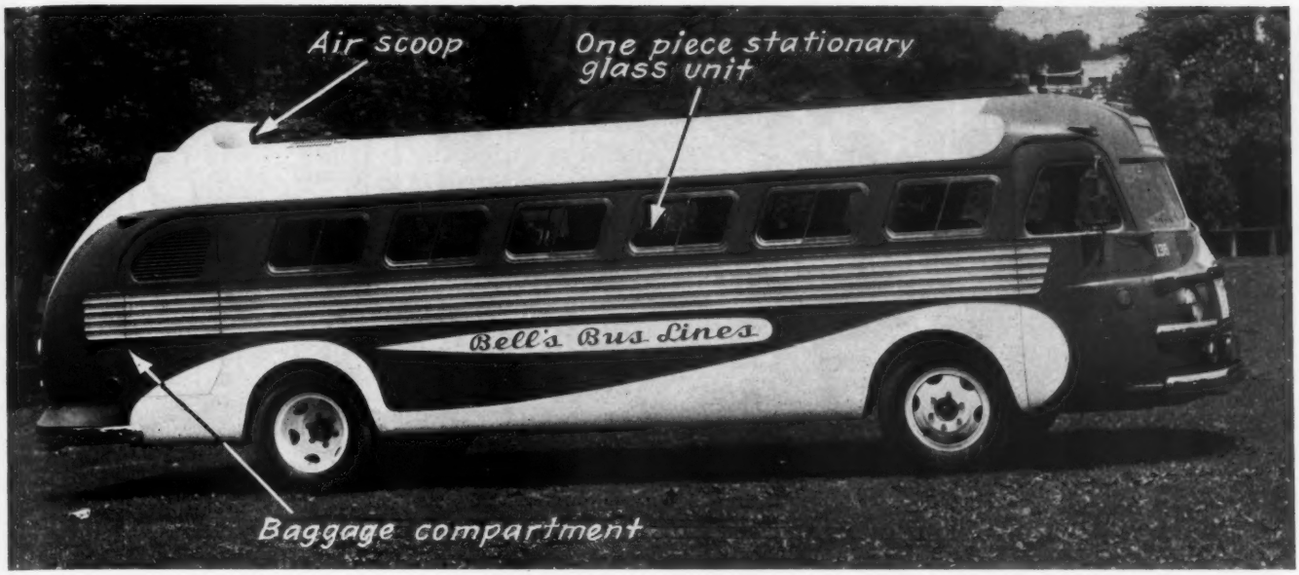


Electric or gasoline motor drives needle and ball bearing mounted pinion shaft through V-belt. Motor and weight of the pump rod operate discharge unit, packing tube and air pump, which forces air and water into the pressure tank, thus cushioning downstroke and balancing the motor load. The lower crankcase serves as an oil reservoir in which the herringbone drive, gear and lower bearings are splash lubricated. The pump slide is split to keep head in alignment and also to facilitate assembly operations.

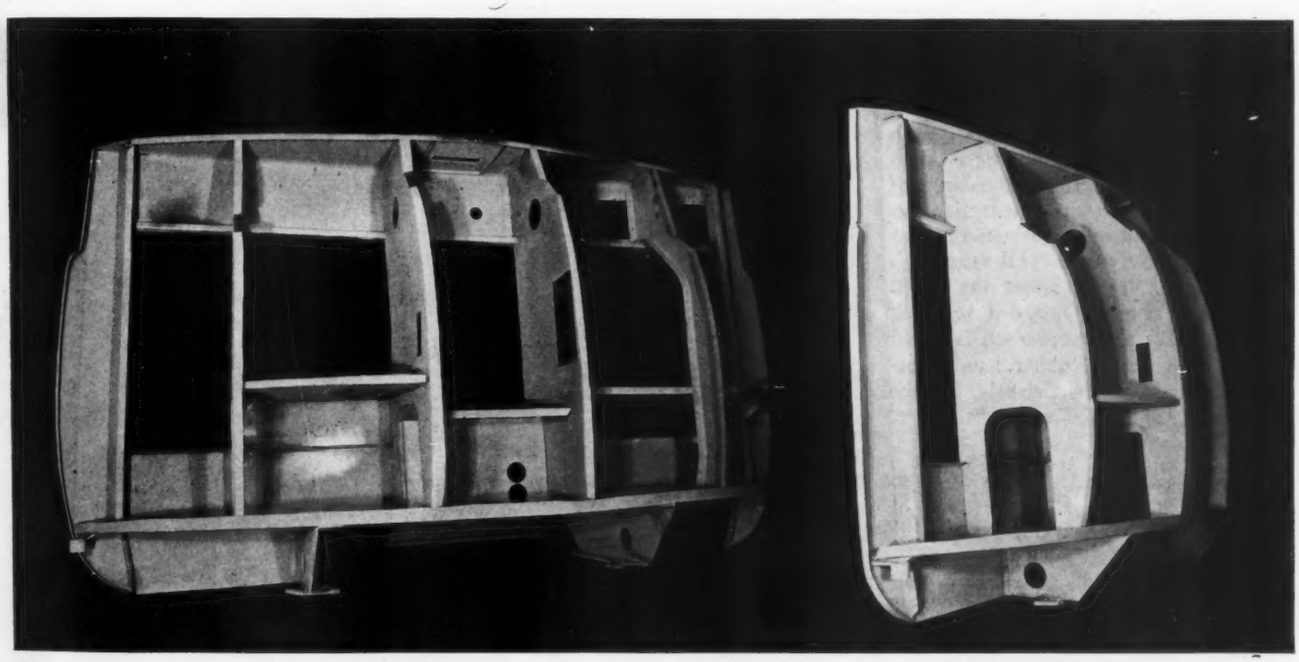


Herringbone drive gear and pitman bearings operate in same plane to reduce overhang from well center, yet provide clearance to remove pump cylinder. Valveless pump delivers oil to top of slide. Openings in slide casting carry oil to polished steel guide rods and to pitman upper bearing. Packing tube has triple-leather plunger, one inverted wiper-leather serving to clean the cylinder. Air pump intake and exhaust valves are rubber seated. Valve chatter is dampened with brass compression springs.

Die-Formed Bus Body

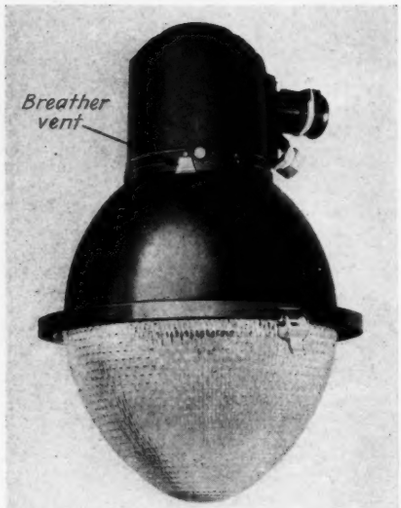


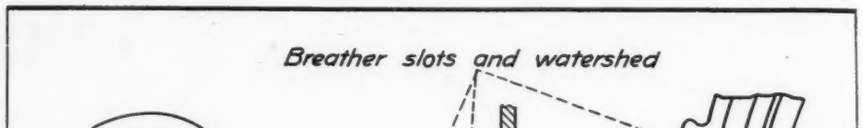
Body and chassis of the Flexible Clippers are built as a unit, almost entirely arc welded, to give maximum strength and durability with minimum weight. Buick engine is mounted on three cylindrical rubber sleeve-type bushings, one at the front end and two at the flywheel end. Engine with its accessories is mounted in cradle in longitudinal direction giving straight drive to the center of the rear axle. Cooling air is taken in by the scoop at the top of the bus and passes it down air tunnel over motor in same direction as in a front motor bus. Air is finally drawn out through louvers in the engine cradle pan. Tubular type radiator is above the engine. Either can be serviced without disturbing the other. Kysor air-operated automatic shutter at the top of the air tunnel maintains constant motor temperature. Fan shroud is part of engine compartment instead of part of rear engine door as heretofore.



Die formed steel body posts, gusset plates, braces, brackets, cross members and longitudinal members are used to secure uniformity of shape. Main frame members run entire length of bus. Cross members extend entire width of body between steel body posts. No structural steel sections are used, all pieces being specifically designed for their particular loading. Front end construction features six heavy gage formed steel vertical diaphragms attached at bottom to heavy member across ends of main frames and at top to heavy cowl member. Top bumper is backed up by one-piece square seamless steel tubing which is welded to all vertical front end members and to belt rail assembly on each side. Roof bows are steel stampings. Steel roof panels and body panels are riveted to the frame. Silentex is sprayed on inside of panels for sealing and along with 1½ in. thick Air-Cell provides insulation.

MODERN DESIGNS — Breather for Luminaires





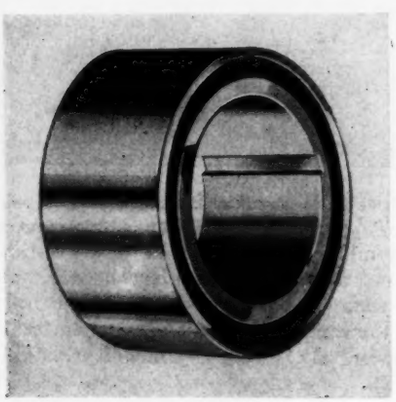
Assembly view showing one of the two watersheds

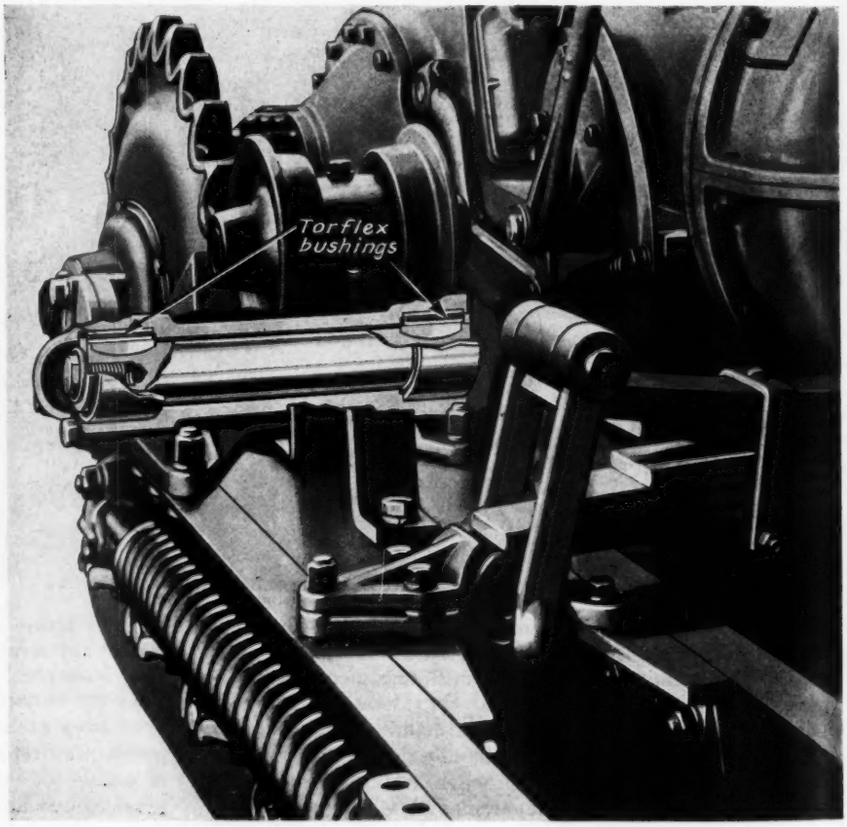
Sectional side view of watershed and "breather"

Bottom view of watershed and "breather" system

Breathing action, as explained by E. B. Karns, street lighting engineer of the Westinghouse Electric & Manufacturing Company, is created in any totally-inclosed street lighting luminaire when the volume of air inside the unit is decreased because of cooling, a partial vacuum being formed when the unit is cooled suddenly by rain or snow. In such weather conditions water will be drawn in instead of air. Inclosed pendant luminaires of the Westinghouse Reflectolux, Jr. type have breather vents in the form of small diagonal slots, covered with weather-proof felt gasket, built into the canopy. These breather vents are closed to keep out bugs and also prevent light from being emitted. Flange over each breather prevents water from flowing into the vent or being drawn in by the breathing action. All other points where moisture might possibly enter are closed by weather-proof felt gaskets.

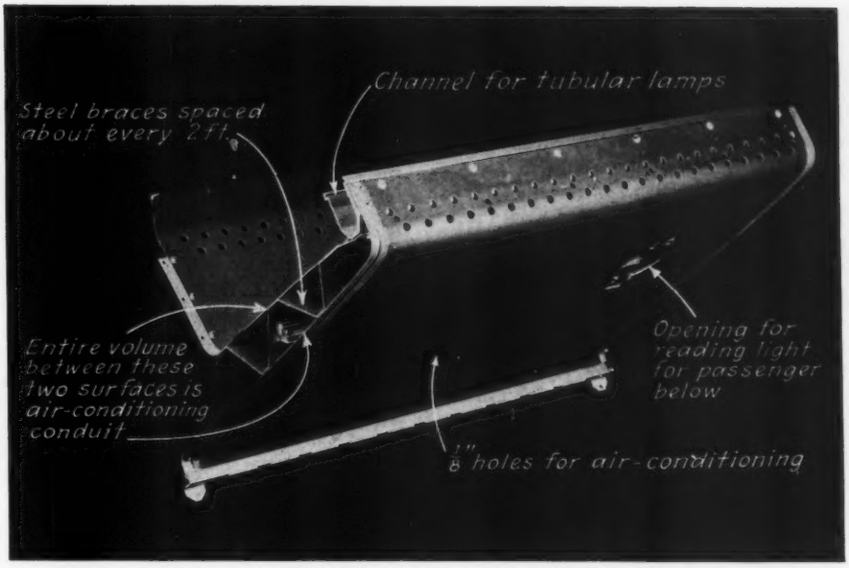
Tractor truck frames, which support the track, are pivoted on a heavy, stationary, high-carbon steel shaft pressed into the transmission case. Allis-Chalmers now uses Torflex bushings of the type shown in the illustration below, instead of grease lubricated bronze bushings formerly used to take the oscillation of the trucks about the shaft. Outer steel shell is fastened to truck frame bracket and inner shell is keyed to the pivot shaft. Rubber bonded between them flexes sufficiently for the small angle of oscillation.

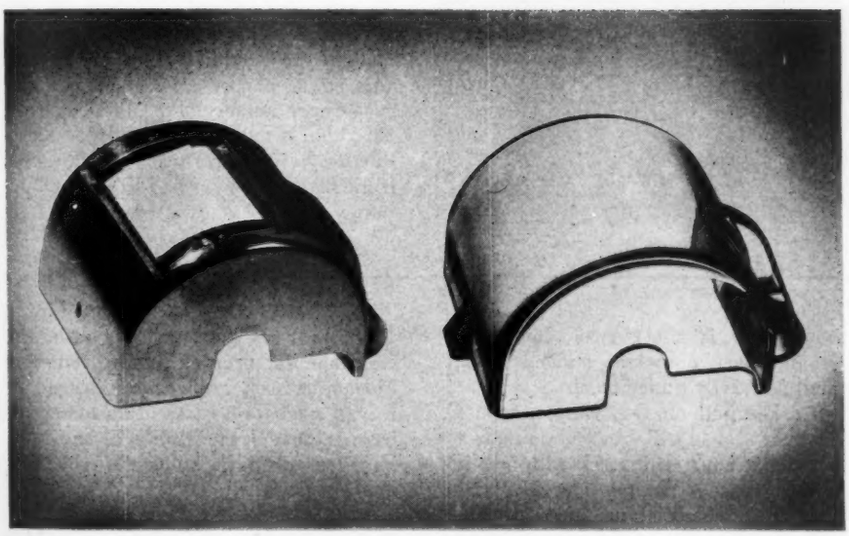




Revises in Bills of Materials

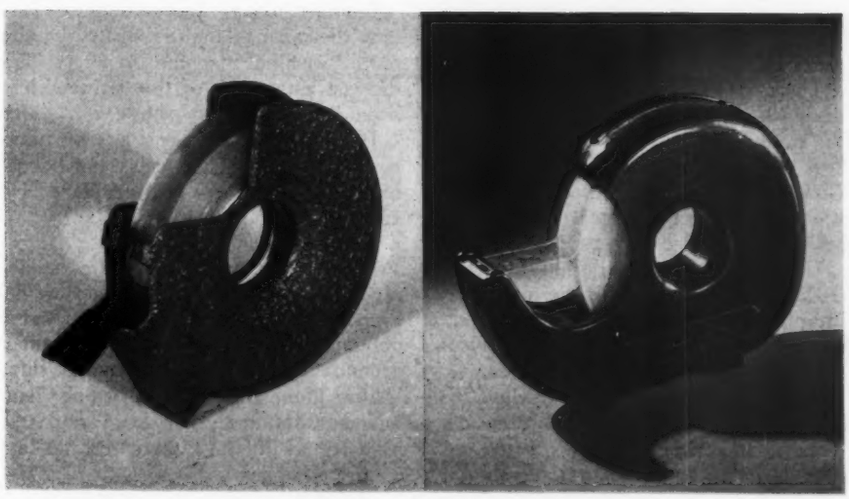
The only metal in this combination luggage rack for Greyhound coaches is in the steel sheet formed braces, bolts, nuts and washers. All the other material is composite laminated sheet known as "Fybre-Tech" produced by Technical Plywoods. The composite sheet consists of two sheets of Peerless insulation (National Vulcanized Fiber) 0.015 in. thick, resin bonded in a hot-plate press to the surfaces of a plywood sheet to give a total thickness of $\frac{3}{32}$ in. The sheets are light and strong, can be bent to a 1-in. radius and can be easily cut, drilled or punched. They are waterproofed after punching the $\frac{1}{8}$ in. vent holes and forming. The design shown here also incorporates the ventilating duct and the channels for the tubular lamps for indirect lighting as an integral part of the baggage rack and also serves as a duct for the electric wiring.

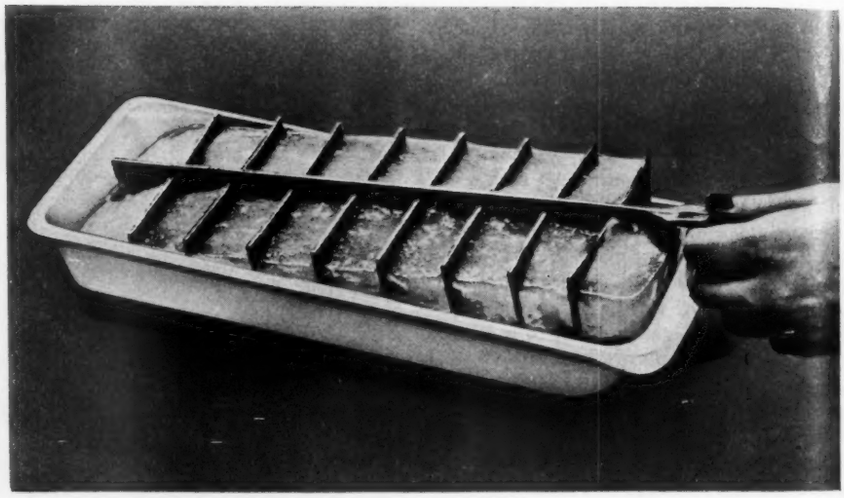

Channel for tubular lamps
Steel braces spaced about every 2 ft.
Entire volume between these two surfaces is air-conditioning conduit
Opening for reading light for passenger below
1/8" holes for air-conditioning



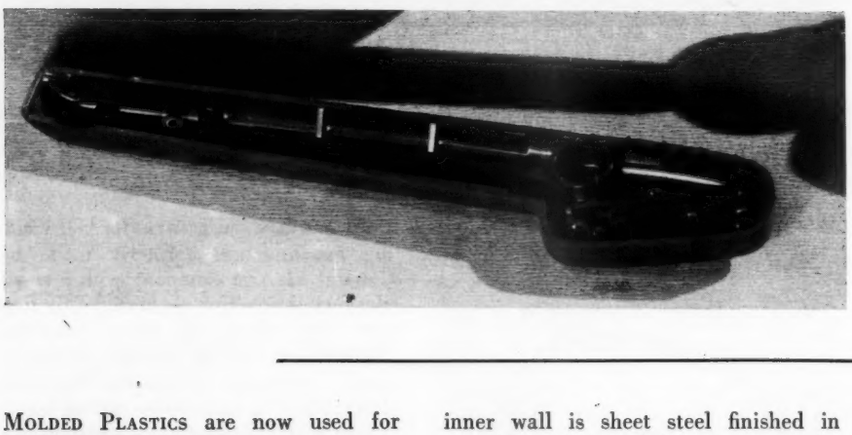
Cast aluminum guard for coil winding machine was formerly made by General Electric Company with a small glass window which permitted only limited observation of the operations. Transparent plastic, methyl methacrylate, was selected to replace aluminum. Advantages in addition to overall transparency include one piece construction and a weight of only half that of the 3 lb. aluminum and glass guard.

Molded phenolic resin replaces the wrinkle finished one-piece steel stampings formerly used for the housing element in the Minnesota Mining and Manufacturing Company tape dispenser. The two-piece housing is held by the friction fit between the outer surface of a hub or boss on one of the two molded housing pieces fitting into the bore of a hub on the other piece. The metal cutting edge, an S-shaped stamping, is held snugly between three knobs which are molded integrally with the housing moldings. The metal cutting-edge stamping also serves to hold the two-parts molded housing in alignment. Design is by Barnes and Reinecke; moldings are by Waterbury Button Company.





Aluminum ice cube trays are now being supplanted by trays of porcelain enamel, tinned steel and plastics. Engineers of the Norge Division of Borg-Warner developed the design shown here. Tray is stamped out of thin sheet steel and coated with white Vinylite which is odorless, tasteless and has no affect on water or foods. Because the steel is thin and the Vinylite is elastic even at refrigerator temperatures, the tray can be flexed easily to eject the ice cubes. The grid in the tray is rubber.



Surface and mechanical noises are claimed reduced by use of molded plastic, instead of metal, tone arm for Webster's new Crystal Pick-up because of damping properties of the plastic. Weight was reduced to such a point that additional weight had to be added for proper balance. Part of the needle cartridge is molded integrally as a production economy. Durez molding was made by General Molded Products Company.

MOLDED PLASTICS are now used for shields and rims of the new Sellstrom safety goggles. Only metal used is in vent screens which clip in opening in side of shield. A high-impact, high strength Durez, phenolic resin, is used.

WOOD, long neglected as a product material, is again getting deserved attention. A number of manufacturers are replacing die-cast handles with handles and knobs of turned wood coated with resin finish. They have very much the appearance of plastic moldings and if designed properly, will last the life of the product.

CHANGES IN MATERIALS used in General Electric Company roasters and accessories for electric ranges, include:

Utensils for the smaller of the two G-E roaster models will be of glass in place of aluminum. The larger roaster will henceforth offer a choice of glass, pottery or enamel utensils.

Single wall aluminum outer shell of the "thrift cooker" for the "C" line of General Electric ranges has been replaced with a double-walled shell; inner wall is sheet steel finished in ground coat porcelain enamel; outer shell is heavily tinned steel.

Cooker pail on G-E ranges, type C, has been changed from aluminum to porcelain enameled steel with all interior surfaces white. The porcelain enamel is a special mix free of lead, arsenic, antimony and other materials that might contaminate food.

Lead-antimony die-castings replace zinc die-castings for the shifter handle on a washing machine wringer. The die-cast zinc cover of this wringer has been replaced by a plastic cover.

Decorative zinc die-castings on automobile instrument panels, hood emblems and horns are being replaced by antimony-lead die-castings.

PORCELAIN ENAMELED grids are replacing aluminum grids in Spiegel waffle irons. Grid is cast iron, with best results obtained by using porcelain enamel ground coat only on underneath side. White porcelain enamel, which had tendency to craze, has been replaced by a frit of different character and tan color.

CAST IRON is getting more attention. One manufacturer of compressors uses Meehanite cast crankshafts instead of forged steel. Two years of customer use have indicated the ability of the Meehanite crankshafts to give trouble free operation.

FLASHLIGHT BATTERY CASE of molded Beetle, urea formaldehyde, replaces metal case formerly used. Molded by Rathburn Molding Corp., case is made in four colors—ivory, red, blue and black. Two halves are hinged by spring clips. Hand button closes contact against base of lamp, spring opens contact when button is released.

MOLDED LAMINATED phenolic resin Textolite sheaves are being used by General Electric on wire enameling machines. Sheaves have ball bearings and are in sizes up to 8 in. in diameter. They replace the aluminum sheave used previously. It is reported that the plastic sheaves do not pick up the coating from wire, the plastic apparently having a lubricating effect that prevents abrasion of the wire coating.

COPPER ZINC ALLOYS — II

Fabricating Characteristics and Physical Properties

R. A. WILKINS and D. S. BUNN
Revere Copper and Brass Incorporated

PART I of this article, August P.E., covered the alpha brasses, those containing 64 percent or more copper. This article discusses the alpha-beta brasses, those containing from 55 to 64 percent copper.

The alpha-beta brasses are much easier to hot work than the alpha; the ease of hot working increasing as the copper content decreases. While lead is virtually insoluble in the alpha brasses and as such interferes with hot rolling, there is reason to believe that the beta phase will hold up to 1 percent of lead in solution, since it is possible to hot-work alpha-beta brasses containing this amount of lead. The alpha-beta brasses are most commonly fabricated by hot processes since they are most plastic under those conditions.

The alpha-beta brasses become increasingly difficult to cold work as the copper content decreases. With less than about 58 per cent copper, they are

Table VII—Deep Drawing Brass

Copper 68 percent — Zinc 32 percent

GENERAL DATA — STRIP

Property	Hard (1)	Soft (2)	Units
Tensile strength	85–96	45–49	1,000 lb. per sq. in.
Apparent elastic limit	55–60	10	1,000 lb. per sq. in.
Yield strength 0.50 per cent extension	64–65	11	1,000 lb. per sq. in.
Yield strength 0.20 percent " offset "	79–86	11–12	1,000 lb. per sq. in.
Yield strength 0.10 percent " offset "	70–77	11–12	1,000 lb. per sq. in.
Elongation (3)	3	55–70	Percent in 2 in.
Rockwell hardness F	106–109	59	1/16 in. ball — 60 kg. load
Rockwell hardness B	85–92	13	1/16 in. ball — 100 kg. load
Rockwell hardness G	60–70		1/16 in. ball — 150 kg. load
Rockwell superficial 15-T	90–92	57–58	1/16 in. ball — 15 kg. load
Rockwell superficial 30-T	78–80	8–5	1/16 in. ball — 30 kg. load
Endurance limit	21	17	1,000 lb. per sq. in.
Young's modulus of elasticity	15,000,000		Lb. per sq. in.
Melting point	1,725		Deg. F.
Density	0.307		Lb. per cu. in.
Coefficient of expansion	0.0000200		Per deg. C. from 25–300 deg. C.
Electrical conductivity	27.20		Percent I.A.C.S. at 68 deg. F.
Thermal conductivity	69.70		B.t.u. per sq. ft. per hr. per ft. (deg. F.)

(1) Refers to 6# hard — 0.100–0.015 mm. grain size at ready to finish.
(2) Refers to 1,200 deg. F. anneal (one hour at temperature).
(3) Apply to strip only (all tests conducted on 0.040 in. stock).

Table VIII—Common High Brass

Copper 66 percent — Zinc 34 percent

GENERAL DATA — TUBULAR RIVET WIRE

	Rod		Forgings		
Property	Hard (1)	Soft	Cold (2)	Cold (3)	Units
Tensile strength	90	42	45–73	80	1,000 lb. per sq. in.
Apparent elastic limit	55	5	14–50	52	1,000 lb. per sq. in.
Yield strength 0.50 percent extension	55	13	22–52	54	1,000 lb. per sq. in.
Yield strength 0.10 percent " offset "	59	11	20–57	57	1,000 lb. per sq. in.
Yield strength 0.20 percent " offset "	65	13	22–62	63	1,000 lb. per sq. in.
Elongation	60	15	52–18	17	Percent in 2. in.
Reduction of area	65	78	75–68	66	Percent
Endurance limit	21	16			1,000 lb. per sq. in.
Modulus of elasticity		15,000,000			Lb. per sq. in.
Rockwell F	104	60	76–102	103	60 kg.— 1/16 in. ball
Rockwell B	82	8	34–79	81	100 kg.— 1/16 in. ball
Brinell	136	56	70–128	135	500 kg.— 1/16 in. ball

(*Continued on next page*)

commercially unsuited for any cold-working operations. The brasses containing between 60 and 62 per cent copper are suitable for parts requiring light cold-working properties, while those above 62-64 percent cold work with slightly more difficulty than the alpha brasses containing 65 percent copper.

Like the alpha brasses, the alpha-beta brasses can be rendered soft after cold-working operations by annealing within the temperature range of 700 deg. F. to 1,400 deg. F., depending upon the properties required The alpha-beta brasses however, can be hardened slightly by quenching from the annealing temperature.

The alpha-beta brasses, being of lowest copper content, and hence with a greater percentage of beta phase, possess the highest tensile properties and the lowest ductility of any of the copper-zinc alloys. The alpha-beta brasses with the higher copper content approach in ductility and strength the alpha brasses containing 65 percent copper.

Muntz Metal containing 60 percent copper, the most important of the alpha-beta brasses, and known also as yellow metal, has an electrical conductivity slightly higher than that of 70-30 brass, has extremely good hot working properties over a wide temperature range, and possesses the highest tensile strength and lowest ductility of all of the brasses.

Muntz metal is widely used for panels, grilles, tube sheets and baffle and support plates in heat exchangers. Muntz metal is fabricated to sheet and strip, plate, rod, bar and tube.

Table VIII—Common High Brass (continued)

GENERAL DATA — COMMON HIGH BRASS STRIP

Property	Hard (4)	Soft (5)	Units
Tensile strength	84–93	44–46	1,000 lb. per sq. in.
Elongation	5	63–70	Percent in 2 in.
Elastic limit	54–58	10	1,000 lb. per sq. in.
Rockwell hardness B	88–92	58–70 (6)	1/16 in. ball — 100 kg.
Endurance limit (at 10^8 reversals)			
soft	13.5		1,000 lb. per sq. in.
4# hard	15		1,000 lb. per sq. in.
8# hard	17.5		1,000 lb. per sq. in.
10# hard	20		1,000 lb. per sq. in.
Young's modulus of elasticity	14,000,000		Lb. per sq. in.
Melting point	1,700		Deg. F.
Density	0.306		Lb. per cu. in.

PHYSICAL DATA FOR COMMON HIGH BRASS AND TUBULAR RIVET WIRE

Melting point	1,700	Deg. F.
Coefficient of expansion	0.0000202	Per deg. C. from 25–300 deg. C.
Electrical conductivity	26.8	Percent I.A.C.S.
Thermal conductivity	69	B.t.u. per sq. ft. per hr. per ft. per deg. F.
Density	0.306	Lb. per cu. in.
Forging range	....	Deg. F.
Type structure	Single phase — alpha	

(1) Refers to rod under 1 in. dia. and cold drawn 50 percent.
(2) Material cold forged from soft rod (5–40 percent reduction of area).
(3) Material cold forged from cold worked condition (40 percent).
(4) 6# hard — 0.070–0.015 grain size at ready to finish respectively.
(5) Refer to 1,100 deg. anneal (1 hr. at temperature).
(6) Rockwell F — 1/16 in. ball — 60 kg.

Table IX—Brass Rod

Copper 63 percent — Zinc 37 percent

	Rod		Forgings		
Property	Hard (1)	Soft	Cold (2)	Cold (3)	Units
Tensile strength	88	47	51–80	83	1,000 lb. per sq. in.
Apparent elastic limit	60	12	25–53	56	1,000 lb. per sq. in.
Yield strength 0.50 percent extension	57	16	31–52	56	1,000 lb. per sq. in.
Yield strength 0.10 percent " offset "	65	15	27–57	61	1,000 lb. per sq. in.
Yield strength 0.20 percent " offset "	74	16	30–65	70	1,000 lb. per sq. in.
Elongation	15	60	50–18	16	Percent in 2 in.
Reduction of area	60	75	73–63	62	Percent
Endurance limit	22	17			1,000 lb. per sq. in.
Modulus of elasticity		15,000,000			Lb. per sq. in.
Rockwell F	104	77	87–100	103	60 kg.— 1/16 in. ball
Rockwell B	86	35	50–82	84	100 kg.— 1/16 in. ball
Brinell	145	71	83–135	140	500 kg.— 10 mm. ball
Melting point		1,680			Deg. F.
Coefficient of expansion		0.0000205			Per deg. C. from 25–300 deg. C.
Electrical conductivity		27.6			Percent I.A.C.S.
Thermal conductivity		71			B.t.u. per sq. ft. per hr. per ft. per deg. F.
Density		0.304			Lb. per cu. in.

(1) Refers to rod cold drawn 50 percent and for rod under 1 in. dia.
(2) Material cold forged from soft rod (5–40 percent reduction of area).
(3) Material cold forged from cold worked condition (40 percent).

Table X—Muntz Metal

Copper 60 percent — Zinc 40 percent

GENERAL DATA — ROD

Property	Rod		Forgings		Units
	Hard (1)	Soft	Hot	Cold (2)	
Tensile strength	80	52	56–60	56–62	1,000 lb. per sq. in.
Apparent elastic limit	50	17	12–19	25–30	1,000 lb. per sq. in.
Yield strength 0.50 percent extension	57	22	17–22	30–35	1,000 lb. per sq. in.
Yield strength 0.20 percent "offset"	66	22	16–22	25–35	1,000 lb. per sq. in.
Yield strength 0.10 percent "offset"	57	22	15–20	25–35	1,000 lb. per sq. in.
Elongation	20	48	55–45	45–40	Percent in 2 in.
Reduction of area	58	70	70–60	65–60	Percent
Endurance limit	25	21			1,000 lb. per sq. in.
Modulus of elasticity		15,000,000			Lb. per sq. in.
Rockwell F	104	84	75–78	90–95	1/16 in. ball — 60 kg.
Rockwell B	88	49	33–45	57–67	1/16 in. ball — 100 kg.
Brinell	151	82	69–79	91–106	10 mm. ball — 500 kg.
Forging range		1,250–1,450			Deg. F.
Forging quality		excellent			
Type structure		Two phase structure — alpha + beta			

GENERAL DATA — STRIP

Property	Hard (3)	Soft (4)	Units
Tensile strength	91–93	56–58	1,000 lb. per sq. in.
Apparent elastic limit	61	13	1,000 lb. per sq. in.
Yield strength 0.50 percent extension	65–66	15.5–18	1,000 lb. per sq. in.
Yield strength 0.20 percent "offset"	77–81	15.5–17.5	1,000 lb. per sq. in.
Yield strength 0.10 percent "offset"	68–72	15–17	1,000 lb. per sq. in.
Elongation	5	45–52	Percent in 2 in.
Young's modulus of elasticity	15,000,000		Lb. per sq. in.
Rockwell hardness F	108	74	60 kg. load — 1/16 in ball
Rockwell hardness B	90	33	100 kg. load — 1/16 in. ball
Rockwell hardness G	66	..	150 kg. load — 1/16 in. ball
Rockwell hardness 15–T	90	72	15 kg. load — 1/16 in. ball
Rockwell hardness 30–T	77	37	30 kg. load — 1/16 in. ball
Endurance limit	25,000	21,000	Lb. per sq. in.

GENERAL DATA — TUBE

Property	Hard (5)	Soft (6)	Units
Tensile strength	88	59	1,000 lb. per sq. in.
Elongation	12	49	Percent in 2 in.
Elastic limit	82	15	1,000 lb. per sq. in.
Rockwell hardness F	109	73	1/16 in. ball — 60 kg.
Young's modulus of elasticity	15,000,000		Lb. per sq. in.

PHYSICAL DATA

Melting point	1,660	Deg. F
Coefficient of expansion	0.0000208	Per deg. C. from 25–300 deg. C.
Electrical conductivity	28.6	Percent I.A.C.S.
Thermal conductivity	73	B.t.u. per sq. ft. per hr. per ft. per deg. F.
Density	0.303	Lb. per cu. in.

AVAILABLE CREEP DATA

(Hot rolled to 0.750 in. dia. rod; grain size alpha constituent 0.020 mm.)

		Rate of Creep Percent per 1,000 Hr.		
		0.01	0.10	1.00
Temp. Deg. F.	No Measurable Flow	Stress to Produce Designated Rate of Creep, Lb. per Sq. In.		
300	up to 7,500	9,000	12,000	17,000
400	approaches zero	2,000	4,750	11,500

(1) Refers to rod cold drawn 30 percent; rod under 1 in. dia.
(2) Material cold struck from forged condition.
(3) 6# hard — 0.045–0.015 mm. grain size at ready-to-finish.
(4) Refers to 1,300 deg. F. anneal (one hour at temperature.)
(5) Cold drawn to 3/4 in. x 0.049 in.
(6) 1,200 deg. F. anneal (one hour).

ALTERING WOUND SPRINGS

To Modify Their Deflection Rates

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BECAUSE of the difficulty of maintaining exact dimensions during the winding of helical springs and subsequent heat-treatment, the commercial tolerance of the spring scale is usually plus or minus 5 percent of the desired value. For some applications such as weighing devices and governors, it is necessary to reduce this tolerance to closer limits. Since it is almost impossible to get the exact scale desired except by trial, a method will be described here for estimating the amount of alteration required when making changes to improve the scale.

If it is desired to increase the scale, that is, make the spring stiffer, active coils can be removed since the spring scale is inversely proportional to the number of turns. Thus, if a given spring has 11 active turns and a scale of 60 lb. per in., and it is desired to increase this scale to 63 lb. per in., the number of turns should be reduced to $60/63 \times 11$, or $10\frac{1}{2}$ turns.

In order to make such a change it may be necessary to anneal the spring, cut off the required number of turns and then increase the pitch of the coils to maintain the desired free or assembled length. This should be followed by heat-treatment to restore the strength of the wire.

The scale can be decreased by placing the spring on an expansion arbor or mandrel, and then grinding some material from the outer portion of the wire, that is, decreasing the outside diameter of the spring. Care should be taken throughout the operation to insure that excessive stresses are not induced in the wire, as a permanent set would ruin the spring.

In discussing the effects resulting from altering the full circular wire section to one which is partially flat, these symbols will be used:

R = mean coil radius of spring, in.
R' = original mean coil radius of spring, in.
X = amount of spring ground away, in.
P = load on spring, lb.
L = length of wire, in.
r = radius of wire, in.
c = distance from center of gravity of section to the point of max. stress in the wire, in.
T = torque on wire, in. lb.
S = maximum torsional stress in the wire, lb. per sq. in.
K = spring scale, lb. per in.
J = polar moment of inertia of wire cross-section, in.^{4}
G = shearing modulus of elasticity, lb. per sq. in.

The basic helical spring equation for the spring scale, that is, load which will deflect spring one inch, is

$$K = \frac{GJ}{LR^2}$$

Since the spring length L is practically equal to $2\pi RN$, and also for a given material G is constant,

$$\frac{K_1}{K_2} = \left(\frac{J_1}{L_1 R_1^2}\right)\left(\frac{L_2 R_2^2}{J_2}\right) = \frac{J_1 R_2^3}{J_2 R_1^3} \qquad (1)$$

in which the subscripts 1 and 2 denote properties of the spring before and after grinding respectively. The basic equation for torsional stress is

$$S = \frac{Tc}{J} = \frac{PRc}{J}$$

For a given loading condition P will be constant. The factor c is difficult to determine for sections of wire partly ground away, since they are no longer circular. If the amount ground off is not great the error in assuming c constant and equal to r will probably be small. Then

$$\frac{S_1}{S_2} = \left(\frac{R_1}{J_1}\right)\left(\frac{J_2}{R_2}\right) \qquad (2)$$

To use Equations (1) and (2) it is necessary to obtain expressions for the polar moment of inertia J, and the radius R, of the section remaining after grinding in terms of the amount ground off X, or the angle α. Fig. 1 shows a dimensioned section through the wire. The point A is the center of gravity of the original wire section, while O is the center of gravity after grinding, the distance between them being d. By applying the principles of determining the properties of an area, expressions can be obtained for the section that remains.

$$d = \frac{2\sin^3\alpha}{3(\pi - m)}\, r$$

J about point O

$$= r^4\left[\frac{\pi - m}{2} - \frac{\sin^3\alpha\cos\alpha}{3} - \frac{4}{9}\left(\frac{\sin^6\alpha}{\pi - m}\right)\right] \qquad (3)$$

where $m = \alpha - \sin\alpha\cos\alpha$
The radius R

$$= R' - d = R' - \left[\frac{2\sin^3\alpha\, r}{3(\pi - m)}\right] \qquad (4)$$

To establish a relationship between X

Table I — Values of K_1/K_2 and S_1/S_2

X/r	α	Values of 10	8	6	4
For K_1/K_2 curves					
0.0	1.0000	1.0000	1.0000	1.0000	1.0000
0.1	0.9649	0.9704	0.9718	0.9763	0.9788
0.2	0.9073	0.9207	0.9241	0.9298	0.9414
0.3	0.8395	0.8615	0.8672	0.8767	0.8961
0.4	0.7650	0.7949	0.8026	0.8157	0.8427
0.5	0.6884	0.7250	0.7345	0.7508	0.7849
0.6	0.6116	0.6532	0.6642	0.6831	0.7231
0.7	0.5356	0.5807	0.5928	0.6136	0.6584
For S_1/S_2 curves					
0.0	1.0000	1.0000	1.0000	1.0000	1.0000
0.1	1.0364	1.0344	1.0339	1.0331	1.0315
0.2	1.1022	1.0968	1.0955	1.0932	1.0887
0.3	1.1922	1.1810	1.1784	1.1741	1.1656
0.4	1.3073	1.2906	1.2865	1.2796	1.2657
0.5	1.4526	1.4277	1.4215	1.4112	1.3905
0.6	1.6350	1.5996	1.5905	1.5759	1.5464
0.7	1.8671	1.8174	1.8050	1.7843	1.7430

and α, it can be seen from Fig. 1 that $X = r - r \cos \alpha$

$$\text{or } \frac{X}{r} = 1 - \cos\alpha$$

By using symbols for the terms inclosed in brackets in Equations (3) and (4), they can be written as

$$J = C_j r^4 \text{ and } R = R'C - d'$$

and the values of C_j and C_d which are independent of the actual dimensions of the spring can be plotted against X/r. Then Equations (1) and (2) may be written as

$$\frac{K_1}{K_2} = \left[\frac{C_{j1}r^4}{(R'-C_{d1}r)^3}\right]\left[\frac{(R'-C_{d2}r)^3}{C_{j2}r^4}\right] = \left(\frac{R'-C_{d2}r}{R'-C_{d1}r}\right)^3 \frac{C_{j1}}{C_{j2}} \quad (5)$$

$$\text{and } \frac{S_1}{S_2} = \left[\frac{(R'-C_{d1}r)}{C_{j1}r^4}\right]\left[\frac{C_{j2}r^4}{(R'-C_{d2}r)}\right] = \left(\frac{R'-C_{d1}r}{R'-C_{d2}r}\right)\frac{C_{j2}}{C_{j1}} \quad (6)$$

Since Equations (5) and (6) are rather cumbersome to use, values have been calculated for S_1/S_2 and K_1/K_2 and listed in Table I, these are plotted against X/r for various values of R'/r in Fig. 2. With these curves, the percent of the wire radius to be ground off for any desired change of spring scale can be found readily. The corresponding increase in stress can be read at the same time.

To illustrate the use of Fig. 2, assume a spring having these dimensions and properties:

Mean coil diameter	1.625 in.
Wire diameter	0.227 in.
Spring scale	80.6 lb./in.
Stress under max. load	50,900 lb./sq.in.

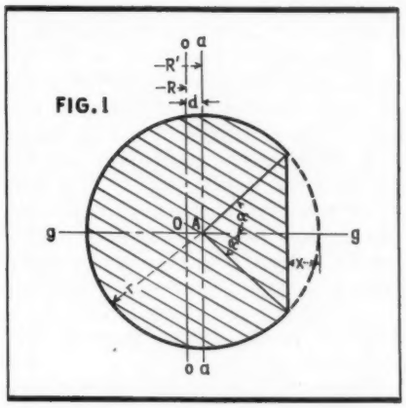

Fig. 1—Round wire with part of cross-section ground away, with dimensions that are used in determining the properties of the remaining section

Suppose it is desired to reduce this spring scale to 75 lb. per in., that is to 75/80.6 or 0.93 of the original value by grinding. The ratio of $R'/r = 1.625/0.277 = 7.15$. By interpolation of Fig. 2, the value of $X/r = 0.193$ so the amount to be ground off is $0.193 \times 0.227/2 = 0.0219$ in. The value of S_1/S_2 for $X/r = 0.193$ is 1.09, so that $1.09 \times 50{,}900$ or 55,500 lb. per sq.in. will be the new maximum stress.

To determine the accuracy of the curves of Fig. 2, a spring was mounted on a mandrel and the outside diameter reduced six times to a final value of X/r of 0.626. After each grinding the spring was removed from the mandrel and the scale measured. In addition, the change in spring scale for a single cut on eleven other springs for values of X/r ranging from 0.97 to 0.825 were obtained. It was not possible to determine the maximum stresses in the wire, so no data were obtainable for the S_1/S_2 curves. The seventeen points obtained agreed quite well with the curves, the maximum difference being 9 percent, at $X/r = 0.626$, and the average 2.3 percent. In general, the theoretical curves give values of K_1/K_2 about 2 percent above the test values. This is within the accuracy to which the distance X can be measured.

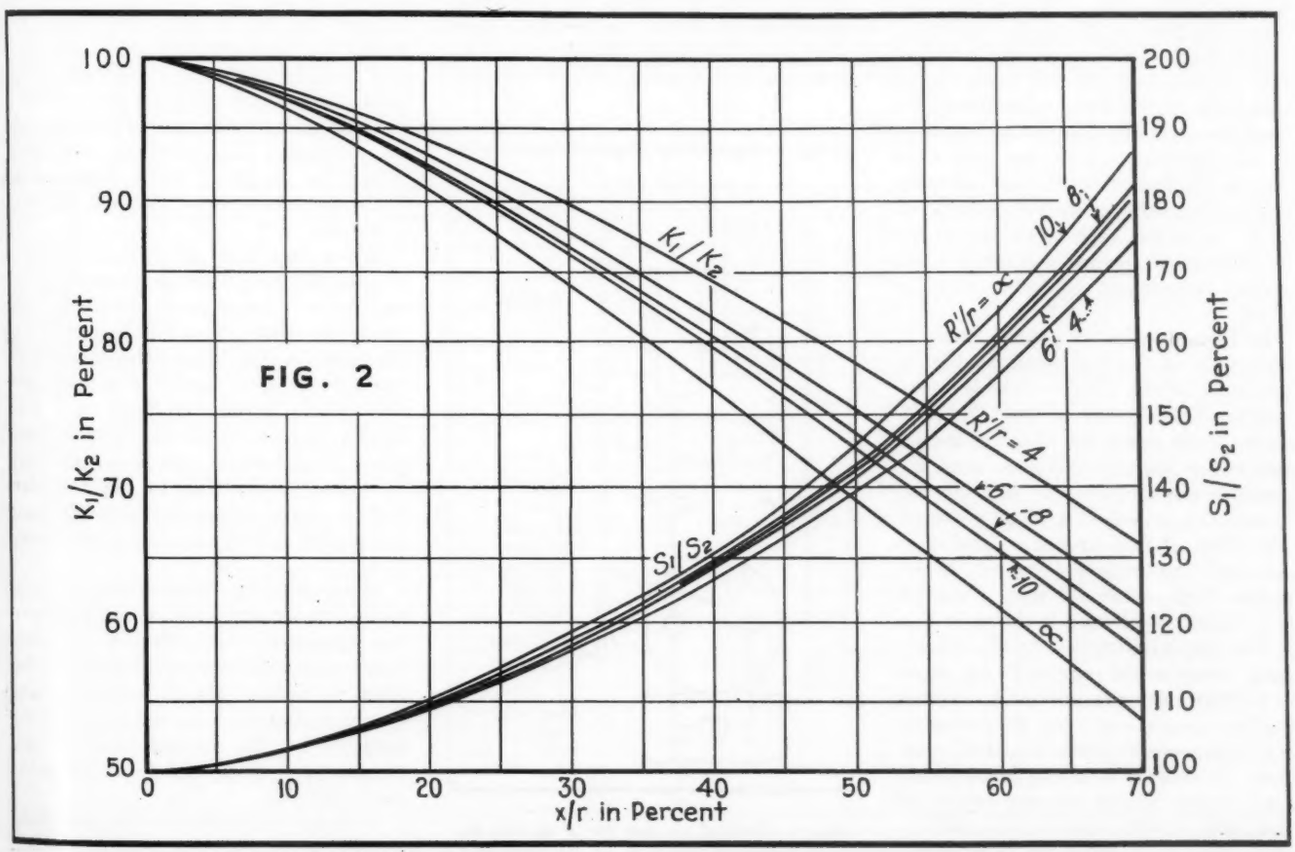

Fig. 2—Curves for determining the percent of wire radius to be ground off for any desired change of spring scale

HYDRAULIC CIRCUITS–II

Selection of Controls for Typical Systems

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ADVANTAGES which are inherent in the use of water and of oil for operating hydraulic units of machines were described in Part I of this article, August PRODUCT ENGINEERING. The first installment also analyzed typical circuits for single-acting rams and described a method for controlling the speed of a double-acting ram when driven by a constant-displacement pump.

Double-acting rams in systems having reversible variable-displacement pumps, as shown in Fig. 6, do not require operating valves. Reversible pumps are supplied with manually or pressure-operated controls to change the direction of their stroke or discharge. Since the areas on each side of the piston are different, the circuit must be supplied with what is known as a differential valve which permits the excess oil from the work side of the cylinder to be discharged back to the reservoir when the ram is on the return stroke.

Variable stroke pumps are furnished with a number of different types of controls. Some manufacturers combine both fixed-displacement pumps and variable-displacement pumps in one unit. Controls are supplied which may be manually, electrically, or hydraulically operated. One of the important assets of the variable-stroke pump is utilized when pressure-responsive controls are supplied.

In certain types of presses, work is done only in the last small portion of the ram stroke. With variable-stroke pumps, controls may be used that will decrease the pump discharge as the resistance or pressure increases until the pump is discharging only sufficient oil to maintain a desired holding pressure. The effect of this type of control is to decrease the required motor horsepower. Performance of such a control in a typical installation is shown in Fig. 7. For this installation a fixed-displacement pump would require 17 hp. input or a 20 hp. motor to provide a required holding pressure of 2,500 lb. per sq.in. With a pressure-responsive control, maximum horsepower would be developed at some predetermined pressure below the maximum, in this instance at 1,500 lb. per sq.in., after which the pump discharge would automatically decrease until at the holding pressure a minimum input of 3 hp. would be required to hold a pressure of 2,500 lb. per sq.in. Fig. 7 indicates that a maximum of 10 hp. would be required for a constant delivery up to a pressure of 1,500 lb. per sq.in. If the cycle is such that the maximum horsepower would only be required momentarily then a 7½ hp. motor would be satisfactory. With these controls the power consumption and the amount of heat generated are reduced. Pressure-responsive controls also make it unnecessary to supply relief valves since with these controls pressure can be limited.

Where high-speed presses are required, it is customary to provide gravity feed to the press ram for the portion of the stroke which is traveled before the work is reached. This type of circuit, as shown in Fig. 8, utilizes a prefill valve which is usually connected to a large supply tank mounted on top of the press. This valve is operated from the main control valve and provides free flow of oil to the cylinder until a load resistance on the press ram causes the hydraulic pressure to build up, at which time the prefill valve automatically closes. The remainder of the press stroke is accomplished by the discharge from the high-pressure pump. When the press is on its return stroke, a pilot connection to the prefill valve causes it to open thus permitting free flow back to the overhead tank.

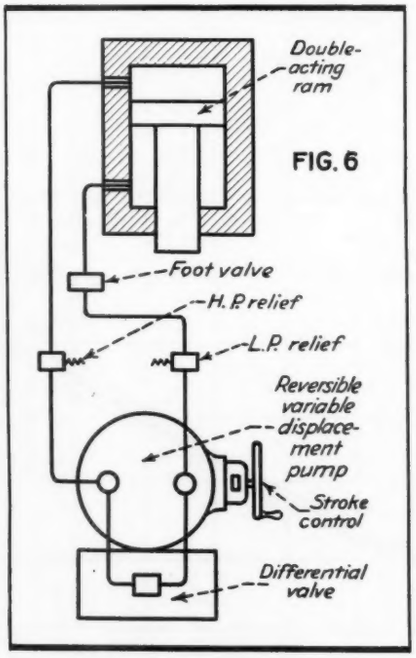

Fig. 6—Typical circuit for a double-acting ram when pump is of the reversible variable-displacement type

Sometimes it is desired to operate two or more rams from one pumping unit. An illustration of this type of circuit would be for a machine tool in which one cylinder was used for clamping and the other to feed the work. Such a circuit is shown in Fig. 9. A control valve is installed between the two cylinders. This valve is an adjustable relief valve and check valve combined. By changing the spring setting of the relief in the control valve, the pressure to the clamping cylinder is varied. When the clamping cylinder reaches the end of its stroke, pressure builds up until the setting of the control valve is reached. The control valve then opens and permits flow to the feed cylinder, at the same time pressure is maintained on the clamp cylinder. When the operating valve is reversed, both rams then return to their starting positions.

When more than one ram or cylinder is operated from a single pumping unit, unless the proper control valves are used, the ram which offers the least resistance will move and the others will remain still. Since pressure is transmitted equally in all directions in a hydraulic circuit, neglecting friction loss, it would be necessary to install a throttle valve in the line to the cylinder with the least resistance in order to have the second cylinder operate at the same time.

Many different combinations of control valves and controls are available for the operations of hydraulic circuits. Solenoid or pilot operated valves can be used to obtain remote control. Cam operated pilot valves or electric switches actuated by the moving parts of the machine are often used to obtain automatic control.

In water hydraulic circuits, velocities should not exceed 20 ft. per sec. In oil hydraulic circuits because of the effect

of viscosity on the friction loss in piping, velocities of 10 ft. per sec. are recommended for discharge piping. If possible, the suction piping should provide velocities around 5 ft. per sec. High suction velocities cause noisy operation and often decrease the capacity of the pumping equipment.

Since certain types of high-pressure pumps require rather heavy oil (1,000 S.S.U. at 100 deg. F.), compared to other types, operators often find these pumps noisy during the first few minutes of operation in cold weather. If the temperature gets too low, it is well to provide some means for heating the oil in the reservoir. Approximately 4,000 S.S.U. is considered the safe maximum viscosity for providing proper suction flow.

In certain types of radial piston pumps operating at high pressures, the minimum viscosity should not be less than 300-350 S.S.U. in order to provide the necessary oil film to support the load of the rotary cylinder on the stationary pintle.

It is usually customary to provide means for cooling the oil in installations requiring operating pressures over 1,500 lb. per sq.in. In certain low-pressure installations, where operation is carried on continuously, it may be necessary to cool the oil.

The amount of heat generated depends upon the loss of energy which occurs in the pump and the various valves in the circuit. Valves that produce considerable leakage represent a high energy loss with corresponding high heat generation. It is for this reason that when ordering valves, the viscosity of the oil should be stated. Engineers have found that certain control valves which are designed to operate with relatively light oils, say 150 to 300 S.S.U. at 100 deg. F., will not function properly when a 1,000 S.S.U. oil is used. Heavier oils require greater clearances in the valves to permit them to function properly.

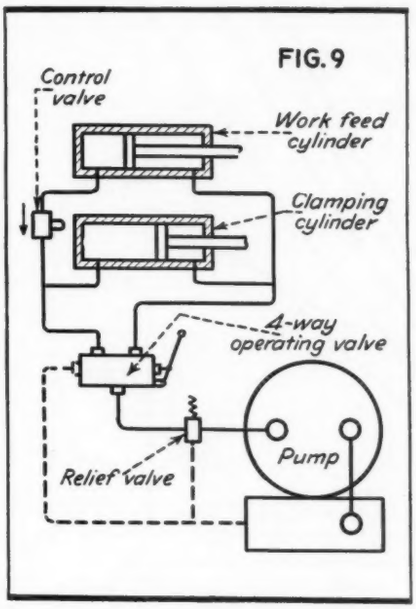

Fig. 9—Circuit for controlling operation of two rams when one pumping unit is employed in the system

Since it is always advisable to design hydraulic circuits so that they can be started up under no load, the motors for operating pumping units are usually of the ordinary normal torque, normal starting current type. The customer quite frequently provides the motors, since he desires to have the motors match the other equipment in his plant, or he may have a preference for a certain type.

The pump manufacturer usually recommends the horsepower of the motor and the speed required, leaving the type up to the customer. There are some installations, of course, where special motors must be used, or provision made so that standard motors can be supplied. One such application is where accumulators are used. Here, when the pump is started, it must immediately develop the maximum pressure as determined by the weights on the accumulator. In order to reduce the size and duty of the pump motor, pump controls may be provided that are operated electrically. One such installation utilizes a solenoid-operated valve operating a stroking cylinder on the pump. The valve is connected to the last point of the magnetic controller so that by the time the motor has practically reached its maximum speed, the pump will be placed on stroke and the motor will be able to

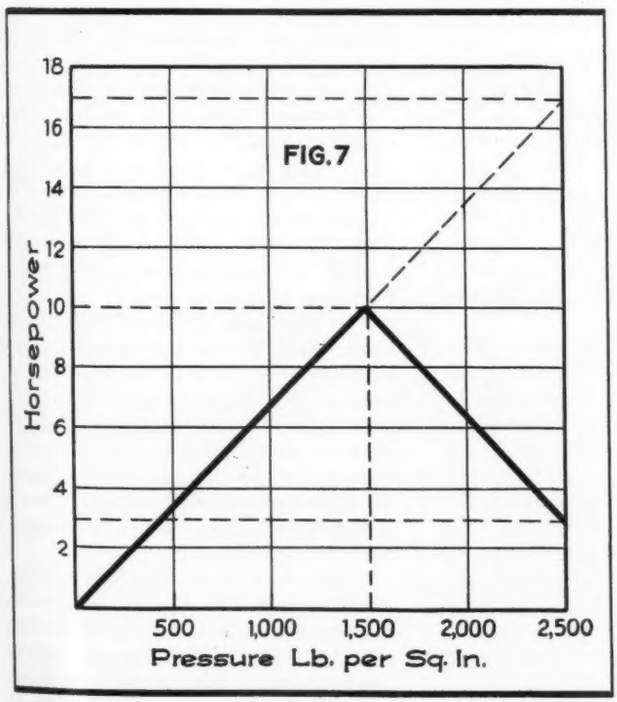

Fig. 7—Performance of a typical variable-displacement pump with pressure-responsive controls

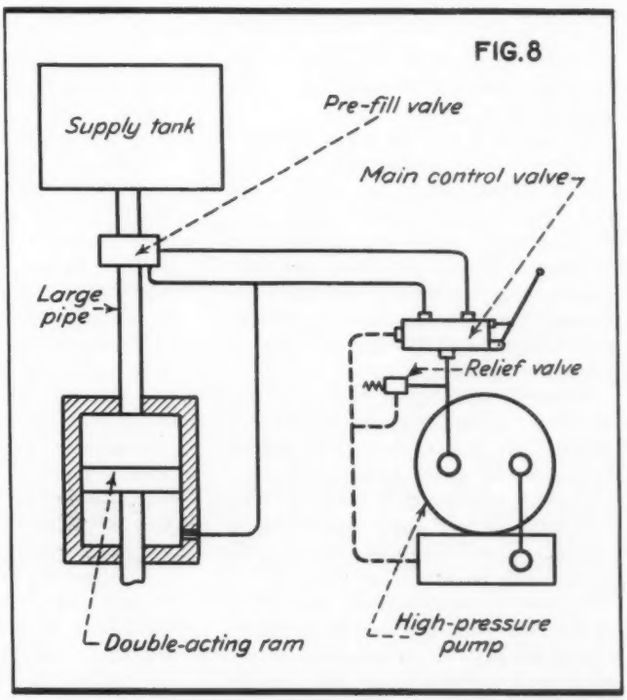

Fig. 8—High-speed press with pre-fill arrangement to provide gravity feed to press while ram is approaching the work

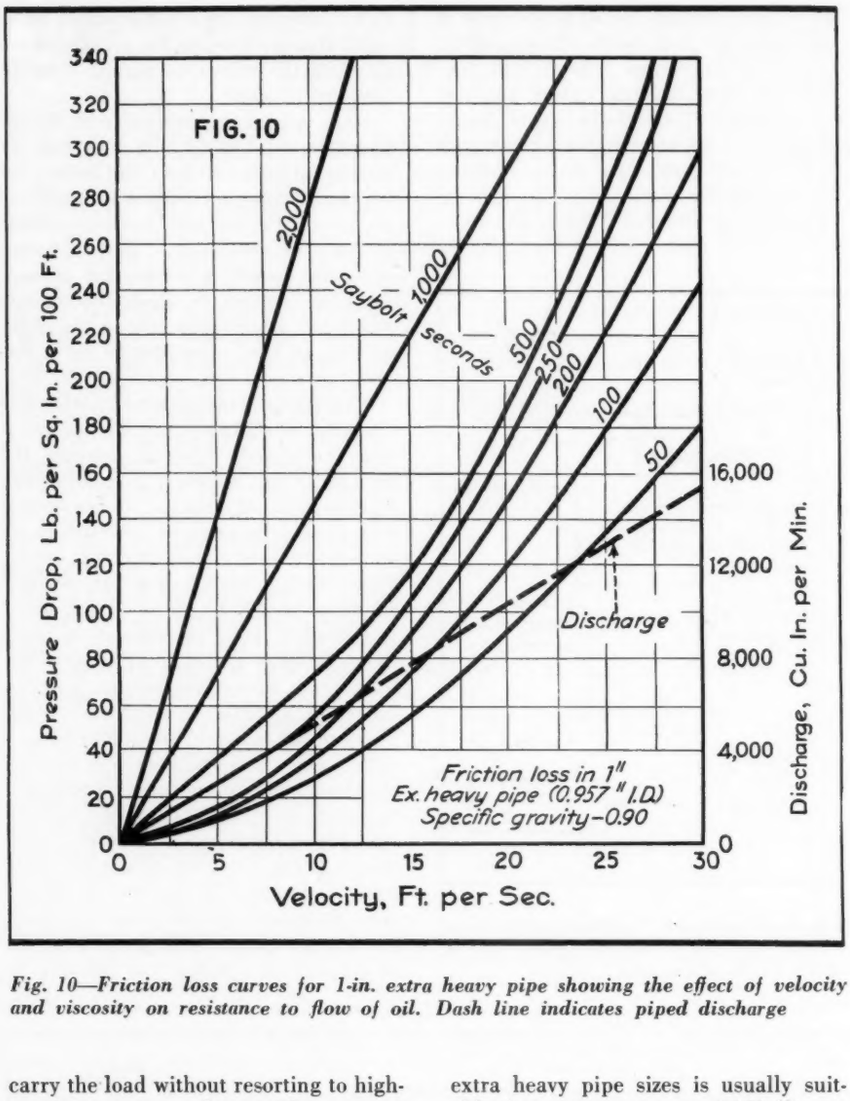

Fig. 10—Friction loss curves for 1-in. extra heavy pipe showing the effect of velocity and viscosity on resistance to flow of oil. Dash line indicates piped discharge

carry the load without resorting to high-starting torque or low-starting current types of motors.

In hydraulic circuits where maximum pressure is only momentary, the horsepower of the motor may be less than the maximum actually required, since motors are capable of instantaneous overloads. Where pressures are maintained or recur with considerable frequency, it may be necessary to provide a motor capable of developing the maximum horsepower.

Seamless steel tubing should be used wherever possible for all high-pressure piping. All joints should be welded. Seamless steel or wrought iron pipe may be used, but it should be cleaned before installing. In fact, the entire hydraulic circuit, piping as well as rams and reservoir, must be absolutely clean and all unfinished surfaces, such as the interior of the oil reservoir in the bedplate, should be painted with an oil-resistant paint. Any particles of dirt that may get into the system will seriously damage the pumping unit.

Seamless steel tubing as furnished in extra heavy pipe sizes is usually suitable for pressures up to 3,000 lb. per sq.in. Suction piping should be furnished equivalent to standard pipe sizes.

Copper tubing is used often for pressures below 1,000 lb. per sq.in. It should not be used, however, if excessive vibration or hydraulic shocks are present. Sudden shocks or vibration cause work-hardening of the copper and ultimate breakage of the tubing.

To obtain the best performance from a hydraulic circuit, it is imperative that the velocities of flow through pipes be kept low. The use of extra heavy or double extra heavy pipe where lighter weight pipe with larger internal diameter could be used, may retard the flow of oil unless larger nominal sizes are used to give an equivalent area.

To illustrate the effect of velocity and viscosity on the flow of oil, and with the aid of the graphs shown in Fig. 10, consider what can happen under various conditions in a 1-in. extra heavy pipe having an I.D. of 0.957 in. Assuming a normal velocity of 10 ft. per sec. using an oil having a viscosity of 350 Sec. Saybolt at 100 deg. F., pressure drop would be approximately 50 lb.per sq.in. per 100 ft. of pipe. If the velocity were doubled or equal to 20 ft. per sec. the pressure drop would increase to 175 lb. per sq.in. per 100 ft. or 3½ times greater.

Also, if a heavier oil were used, say one having a viscosity of 1,000 seconds at 100 deg. F., the pressure drop per 100 ft. at a velocity of 10 ft. per sec. would be approximately 145 lb. per sq.in., while at a velocity of 20 ft. per sec. with this same oil, the drop would be 290 lb. per sq.in., or twice as much as at 10 ft. per sec. From this it is seen how the viscosity of the oil affects the pressure drop and consequently the flow.

Since the viscosity of oil decreases with temperature increase, the pressure drop or friction loss will also decrease. This is caused by the high friction loss caused by the viscous oil which gradually decreases as the oil becomes heated and the viscosity decreases.

A perfect fluid for a hydraulic system would be one having constant viscosity at all temperatures. Since this cannot be obtained, an oil having the least change in viscosity should be selected. Such an oil is described as one having a high viscosity index.

Since the viscosity of oils decreases with increase in temperature, a point may be reached where the viscosity is so low that the pumping unit is unable to provide the necessary pressure because of leakage of the oil past the moving parts. Also a point may be reached where the full capacity of the pump is going to leakage and no pressure is developed. The viscosity, therefore, greatly affects the efficiency of the pumping unit and, in fact, the entire system. When the oil gets too thin, excessive leakage occurs in the valves as well as in the pump and this loss in energy being transformed into heat, increases the oil temperature rapidly with a consequent decrease in viscosity.

It is important, therefore, that the oil temperature be maintained within reasonable limits so that the viscosity is changed as little as possible. The usual maximum limit for the temperature is 30 deg. above the ambient or say a maximum of 130 deg. F. Some form of oil cooling should be provided where operating conditions result in higher temperatures.

As shown by Norman E. Miller in the article "Hydraulic Fluids" (PRODUCT ENGINEERING, p. 407, Sept., 1940, and p. 450, Oct., 1940), the success with which a circuit and machine perform their intended functions depend to a great extent on the selection of the proper type of oil.

PORCELAIN ENAMELED PARTS

Design Factors That Promote Quality

FOR SATISFACTORY porcelain enameled parts the sheets from which they are made should be of uniform composition, absolutely flat, and should have the ductility necessary for required drawing, forming or stamping operations. The metallurgical structure of the sheet should be such that a strong bond will result between the porcelain enamel and the metal when fired.

In general there are three grades of enameling iron: (1) That suitable for parts where the property desired is non-sagging; (2) Enameling sheets suitable for fabricated parts where both drawing and non-sagging qualities are necessary; and (3) Enameling sheets suitable for extra deep drawn parts where the drawing properties are the chief consideration and the non-sagging properties are not important.

The difference in the requirements demanded by the many different types of products which are porcelain enameled make it difficult to formulate a general rule by which the proper gage of metal can be determined. Many companies conduct shop trials in order to develop designs that result in a minimum number of throw-outs in the finished units. When the quantity to be produced does not warrant the expense of shop trials and there is no past experience to guide the designer, the gages indicated in Fig. 1 are recommended as minimum thicknesses of sheets for parts of moderate size, in which requirements for rigidity and flatness are not highly exacting. The enameling sheets should be as heavy as cost considerations will permit. The thicker the sheet the deeper will be the possible draw and the less the tendency to warp when fired. In general, the larger the flat areas and the greater the degree of surface flatness demanded, the greater is the sheet thickness required.

Thinner sheets can be used if there are flanges, reinforcements or embosses to stiffen or reinforce the flat surfaces. The more rigid the design of the part, the better it is for enameling.

Corner radii must be great enough to prevent the surface tension of the enamel, when molten during firing, from stretching the coating thin over the corner surfaces. Thin coatings at corners are likely to be overfired, thereby causing spots, greenish color cast, and a tendency to chip. Corners should be formed as shown in Fig. 3 (B), so that the radius at the surface to be enameled is not less than $\frac{3}{16}$ in. A larger radius should always be used where possible.

Flat or nearly flat surfaces should have rolled or beaded edges to prevent warping in firing. It is good practice to make reinforcing flanges not less than $\frac{3}{8}$ in. wide. If the flanges are to have holes for bolts or screws, a greater flange width is desirable. A flange depth of $\frac{5}{16}$ in. usually is not strong enough to prevent warping. When adjacent edges are flanged on a press, the corner opening should be welded as shown in Fig. 2(A) to reinforce the panel. The failure of the part shown in Fig. 4 was contributed to by the lack of a gusset to reinforce the part at each end of the roll. Flexing of the metal in the flange during assembly or handling caused failure.

It is difficult to keep long flanges, which are an inch or more wide, straight and at an exact angle unless they are properly supported during the enamel firing operation. The flange designs shown in Fig. 5(A) and (B) provide little or no support for maintaining the main flange at a 90 deg. angle during firing. The design shown in Fig. 5(C) is far more satisfactory when properly proportioned. Flanges *A*, *B*, and *C* should be of equal width and they should not be less than one-third the width of flange *D*. If for some reason it is not possible to hold the dimensions to this ratio, light gage angles can be spot welded to flanges *A* and *B* as a reinforcement. However these angles should never be welded to the back of a surface that is to be enameled because the double thickness of metal at the area of attachment may prevent uniform heating of the surrounding areas and result in underburning, that is, a condition in which the enameled coating is not thoroughly processed or fused.

If the underside of an exposed surface must have a lug, reinforcement or other part welded to it, the total thickness of the double metal should be a minimum. Light gage metal for the welded-on part will help. If practicable, grinding away part of the panel thickness at the area of attachment will aid in preventing underburning.

Large panels should have all edges flanged and tack welded to hold them straight. For good covering with cover coat enamel, corners should be solid welded or drawn. Failure of the part shown in Fig. 6 was undoubtedly caused by improper design of the corner which was not strong enough to resist strains in assembly. Metal should not be folded back onto itself, for when this is done pockets are formed which trap cleaning and pickling solutions; also the double thickness of metal will cause thermal strains during enameling.

Flanges which serve only as extensions for fastening in assembly or for holding the part in a correct position in relation to the body or adjacent parts are usually relatively wide and protruding. Such flanges will generally warp and bend easily. Assembly flanges

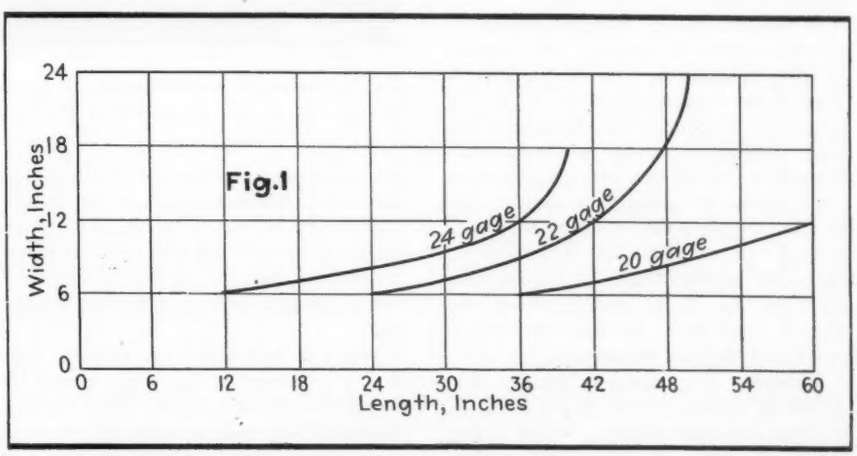

Fig. 1—Recommended minimum thicknesses of sheets for parts to be porcelain enameled

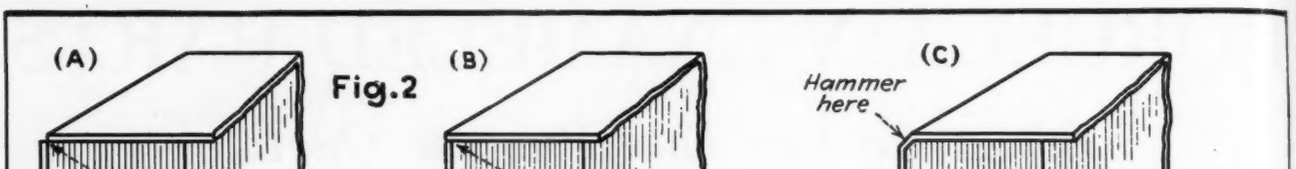
(A)
Fig.2
(B)
(C)
Hammer here
Correct for welding. Metal can flow off both edges and through joint to opposite side
Wrong for welding. Welder will flow metal from edge of plate leaving seam open on inside
Peening weld with a hammer tightens metal in panels and decreases hairlines

Fig. 2—Correct and wrong designs for welded corner joints for porcelain enameling. Design shown at A is correct

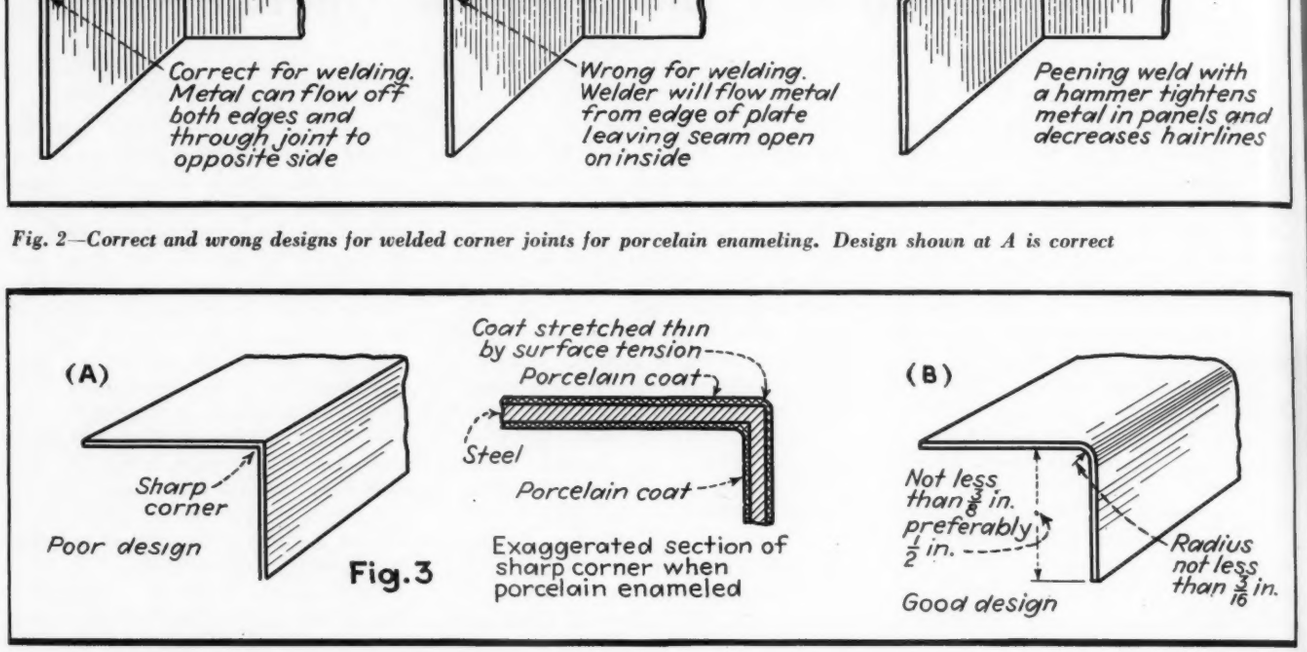

Fig. 3—Surface tension of enamel when molten draws the coat thin over sharp corners with resultant overfiring. Corner radius over enamel should be not less than 3/16 in. for proper coverage if burning and overfiring are to be prevented

should be weakened by notching, as shown in Fig. 7 at locations adjacent to the assembly point so that they will bend without transmitting strains to the enameled surface or to the adjacent holding flange.

Notches or cutouts may produce an area of local weakness where warpage may occur in firing or where bending may be concentrated, with resulting chipping of the enamel during assembly. Large cutout openings in panel parts are a cause of warping and should be avoided. Holes and notches produce uneven draining of ground coat thus requiring special processing.

In designs where flange notches or cutouts cannot be avoided, the corners of the opening as shown in Fig. 8 should be rounded with a ¼ in. or larger radius in order to add strength to resist flexing. The weakness inherent in such a design can be diminished to some extent by setting the cutting die so that it will push or burr the metal toward the inside of the flange along the edge of the notch or cutout. An excellent design of slot is shown in Fig. 9. Note how the edge is turned down and the end cut away.

Embosses or pressed-in designs for stiffening should not be closer than ⅜ in. from the edge of the panel in order not to overstrain the metal during the forming operation. A prevalent cause of

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Fig. 4—Improper reinforcement of corner contributed to this failure. Lack of gusset at each end of the roll permitted flexing of flange with resultant chipping

hairlining is strained metal. While many parts of complicated design are strain relieved by a heat-treatment, as a rule such treatment is not practical for mass production because of the extra time and equipment necessary for the operation.

Edges of bolt holes and notches that will be visible in the final assembly should be turned inwardly from the exposed surface with a radius of not less than $\frac{3}{16}$ in. This is necessary because of the inherent property of the enamel when molten to pull away from sharp edges thus resulting in overfiring and burning off at corners.

Holes for mounting should never be close to an emboss or flange because any bending of the metal when the mounting bolts are tightened may cause chipping. Holding clips and lugs should not be welded on the back close to an edge bead or an emboss for the same reason.

Brackets should be made from sheet having a thickness less than that of the part to which they are welded. Exces-

sive metal should be cut out of the contact areas of the bracket or lug in order to reduce thermal strains. Also, brackets should be weakened by notches so that they will not transmit bending strains to the exterior panel surface. Brackets should be placed so that the welded area is not near an edge that is to be cover enameled; they should be an inch or more from the edge, bend or enamel bead. The rear view of the part shown in Fig. 10 shows excellent location and design of lugs.

The design engineer's interest in the appearance of a product requires that he be familiar with the decorative possibilities of brushing, in order that he can blend its necessity into a pleasing harmony with the basic design. Brushing or edging is the removal from certain areas of the finish enamel coat before firing. After brushing, the thin black or dark colored base coat is exposed. This base coat because of its thinness is more nearly proof against damage in assembly, shipment and service.

When enamel is built up to an excessive thickness it is much more liable to crack or chip off, than when used in relatively thin coatings. A study indicated that losses caused by chipping in assembly were nearly seven times greater on parts with enamel thicknesses greater than 0.021 in. than on parts having coatings less than 0.018 in. thickness.

Enameling technique has developed to such a degree that excellent results can be obtained on corner rounds without brushing. However, the edges of holes and all corner rounds on parts the edges of which are adjacent to other parts or to the frame when assembled should be brushed. By careful designing, screw holes can sometimes be located so that brushing is not visible after assembly.

When bolt holes and cutouts in parts are not visible in the assembled product, the face of the part should be brushed down to the ground coat or first coat with at least 1/8 in. rim of ground coat exposed around the hole. If accessories are fitted over holes or cutouts, brush at least 1/8 in. beyond the outside dimension of the accessory. Brush at least 1/8 in. around entire

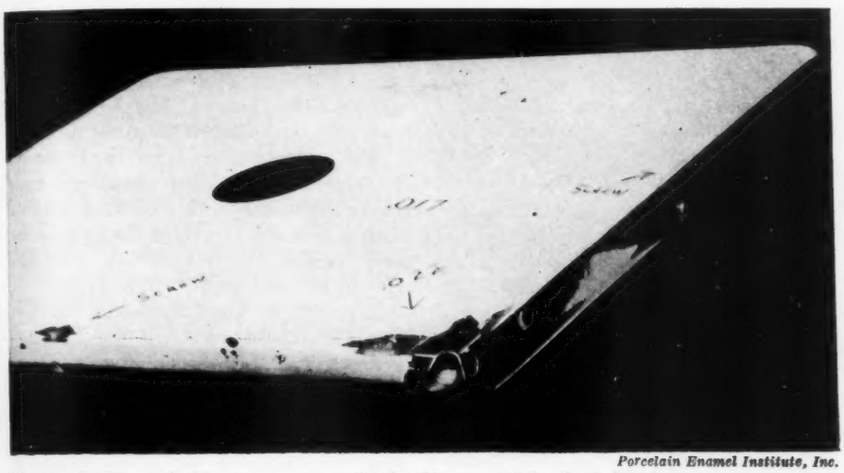

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Fig. 6—Failure of this piece was undoubtedly caused by lack of strength at corner to resist strains imposed during assembly

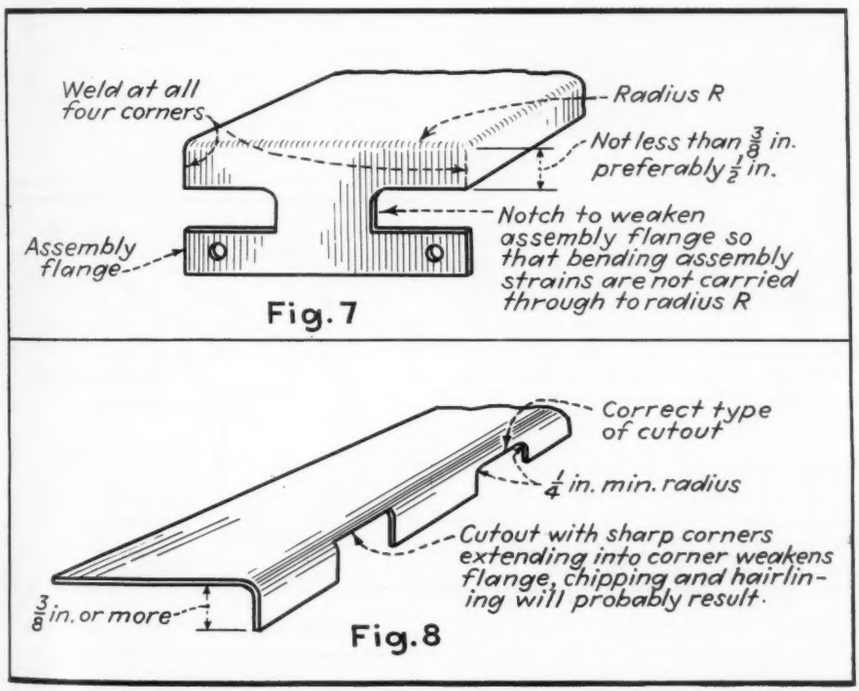

Weld at all four corners
Radius R
Not less than 3/8 in. preferably 1/2 in.
Notch to weaken assembly flange so that bending assembly strains are not carried through to radius R
Assembly flange
Fig. 7
Correct type of cutout
1/4 in. min. radius
Cutout with sharp corners extending into corner weakens flange, chipping and hairlining will probably result.
3/8 in. or more
Fig. 8

Fig. 7—Assembly flanges on porcelain enameled parts should be weakened by notches so bending strains will not be transmitted to panel surface. Fig. 8—Sharp right angled cutouts weaken flanges causing chipping. Corners of cutouts should be rounded

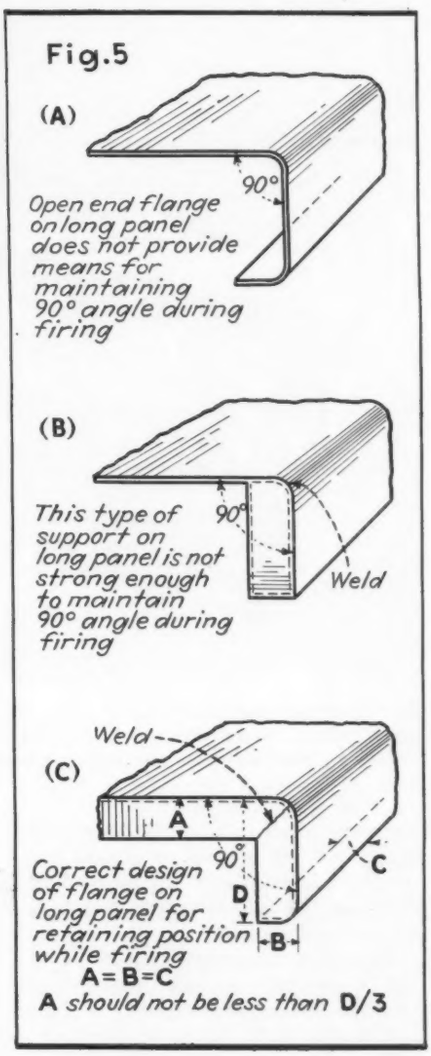
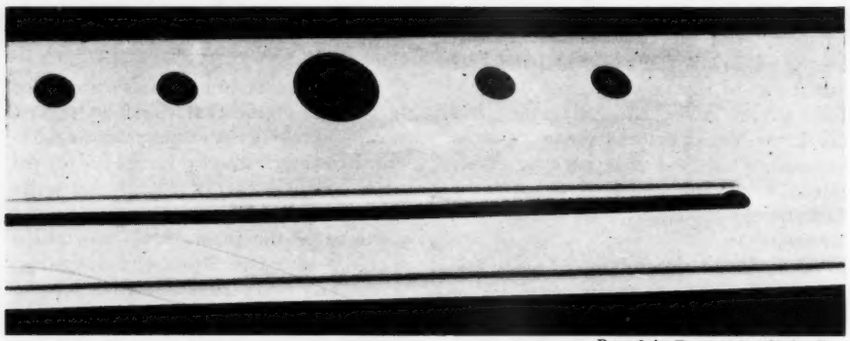
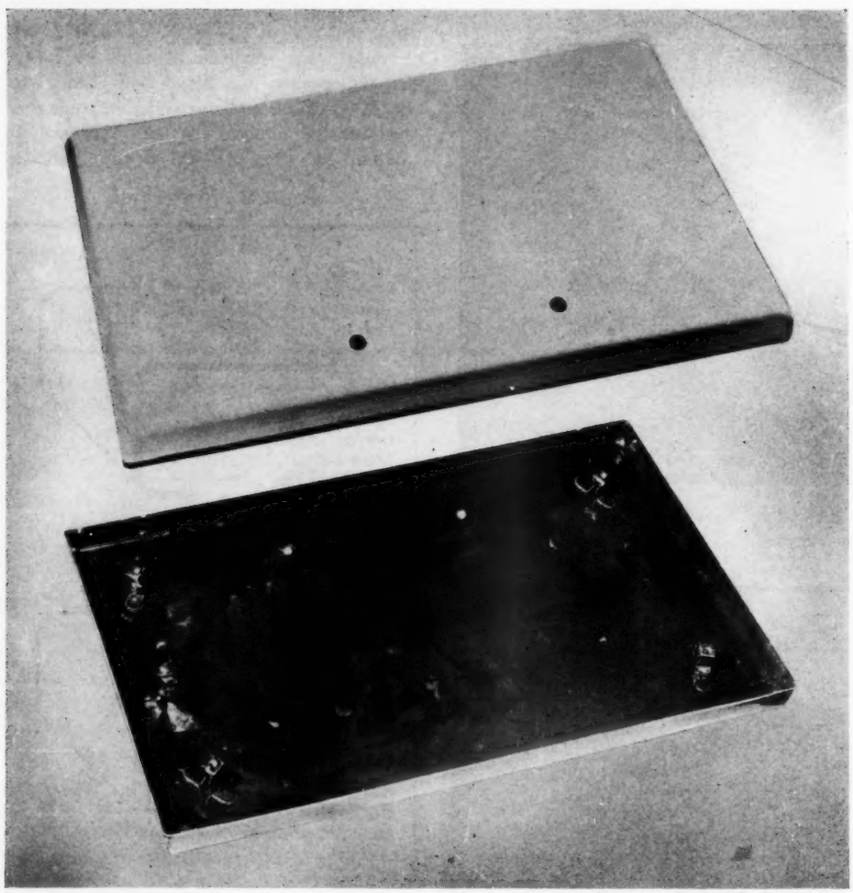


Fig. 5—Incorrect and correct methods of stiffening flanges at corners on long parts to maintain desired flange angle



Porcelain Enamel Institute, Inc.

Fig. 9—Design with slot properly turned down and cut away at the end. Note the radii at both the end and along the turned down portion of the slot



Porcelain Enamel Institute, Inc.

Fig. 10—Front and rear views of porcelain enameled panel. Proper radius at corners and brushing holes prevented chipping or hairlining. Lugs welded on back are properly placed and give minimum amount of double thickness metal

perimeter of all large parts. To protect edges, it is not unusual at cubical corners to increase the width brushed up to ½ or ¾ in., blending it into a decorative design.

An important consideration in the design of porcelain enameled parts which are fitted or fastened together to form an assembly is the matter of clearances. Sufficient space, of course, must be provided between adjacent parts to allow for maximum enamel thickness in addition to the maximum sheet metal tolerances. In general, the thickness of the porcelain enamel coat will vary from about 0.010 to 0.018 in. at the center of panels. At edges when beads are present the maximum thickness of coat may be as great as 0.05 in. These dimensions are for coatings on one side of the sheet, so that the total thickness of sheets that are enameled on both sides will be the thickness of the metal plus twice the coating thicknesses indicated. To prevent chipping in assembly that results from tight joints, the clearance for the enamel alone should be not less than ⅛ in. for each part.

Still greater clearance should be allowed on parts that fit into inside corners, like that shown in Fig. 11, because the ground coat enamel may accumulate at interior fillets which happen to be at the bottom during the draining operation. With such joints a clearance of ⅛ in. should be allowed for the enamel. A similar allowance must be made for excess metal on the inside of welded corners, as the welding metal runs through the joint and increases the thickness back of the weld.

Allowance should also be made in design for the accumulation of enamel in attachment parts such as brackets, spacers and screw pockets. Screw pockets enameled with a ground coat should be $\frac{3}{32}$ in. deeper than the thickness of the screw head. The width of the pocket should be as large as possible and yet not permit the screw head to turn.

For spacers a uniform thickness is important since slight variations may cause tight fits with resulting strain. Either asbestos or rubber backed washers, paper or composition washers should be used under screw heads.

It should be noted that since the porcelain enameling industry is not standardized, one manufacturer may be at variance with another in regards to satisfactory proportions of details, because of differences in equipment for fabrication. Provisions in design for supporting the part during drying and firing should be arrived at after a consultation with the enameler. The designer, however, when proportioning parts and specifying contours should not forget that simplicity in design not only enhances appearance but also promotes ease in enameling.

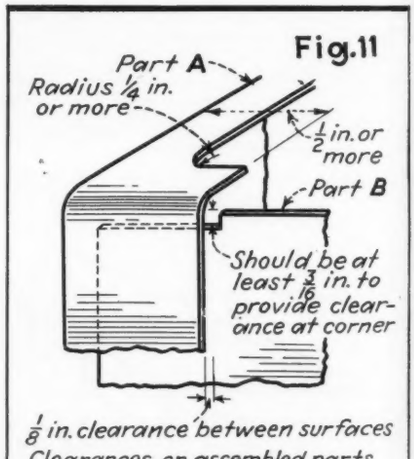
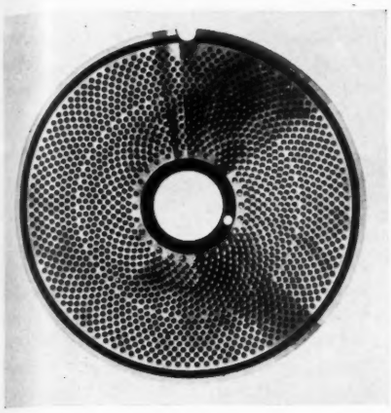


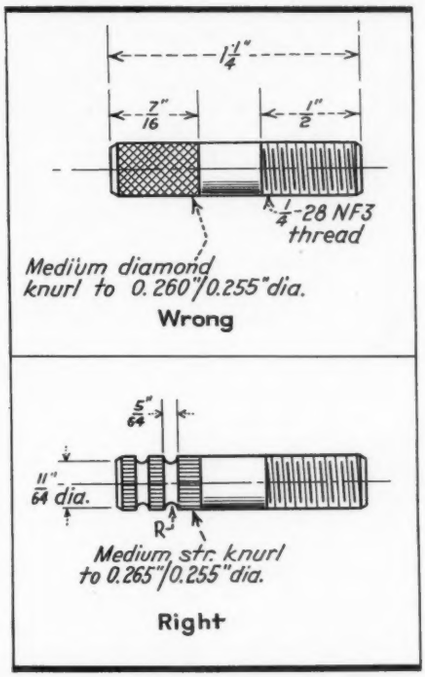
Fig.11
Part A
Radius ¼ in. or more
½ in. or more
Part B
Should be at least 3/16 in. to provide clearance at corner
⅛ in. clearance between surfaces
Clearances on assembled parts before enameling

Fig. 11—Detail of corner and panel assembly showing proper clearance

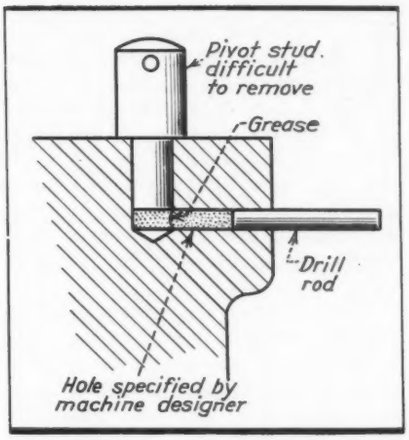
Causes and Cures



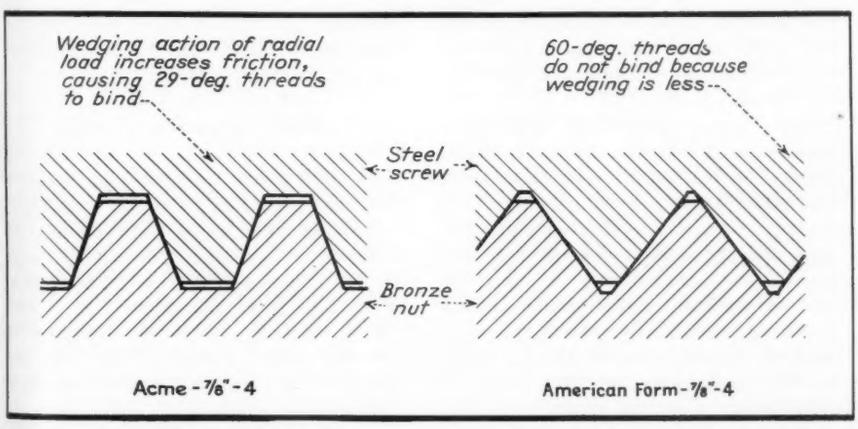
Closely spaced holes in this 8¾-in. diameter meat grinder plate often broke through the thin walls during drilling. Steel used was SAE 1020; holes are templet-drilled with high-speed drill because they are too close for multiple drilling. Plate is hardened after machining. Rejects were greatly reduced by changing the steel specification to X1515, a free-machining, fast carburizing open-hearth steel which has manganese and sulphur distributed throughout its matrix. Sulphur aids dry machining, but not enough is present to make the steel brittle. The Korrect Kutting Manufacturing Company reports that change of steel also reduced drilling time 54.4 percent, facing time 41 percent, and drill breakage by half.



Studs die-cast as inserts into the zinc alloy housing of a gear box unit often pulled loose when the cover was drawn down with nuts. These studs had a medium diamond knurl on the anchored end. By redesigning the studs with grooves and a medium straight knurl as shown, anchorage of the insert was sufficiently improved.



A pivot stud near the edge of the platen was required by a special function of a wire forming machine. It was difficult to remove these studs for replacement and occasionally the shanks had to be drilled out. This problem was met by specifying that a small hole be drilled into the side of the stud hole. When this is filled with grease, and a piece of drill-rod is driven in as shown, the stud is easily forced out by hydraulic pressure.


Wedging action of radial load increases friction, causing 29-deg. threads to bind
60-deg. threads do not bind because wedging is less
Steel screw
Bronze nut
Acme - 7/8" - 4
American Form - 7/8" - 4

Rudder and elevator tabs on an experimental airplane were operated by means of a ⅞—4 Acme steel screw and bronze nut. Investigating the cause of considerable friction between screw and nut, engineers traced the difficulty to a radial load on the screw. The 29-deg. angle of the Acme thread caused wedging action and consequent bind. Changing to a ⅞—4 American thread resulted in a free fit when assembled, eliminating the trouble.

STEEL WIRE BRISTLES have been found to be unsuitable for power brushes used to remove flux from non-ferrous and corrosion-resistant alloys. Steel particles from the bristles become imbedded in the metal being cleaned. When these particles rust, they act as nucleuses for minute electrolytic cells which corrode the sheet. To prevent this, nickel alloy bristles are used.

RUBBER-COATED FEEDER CABLE, for 5,000 volt service as trailer cable on electric shovels in copper strip mines, gave good service in ordinary use. The heavy rubber jacket was needed to withstand severe abrasive wear. However, when shovels were put into service at an altitude of 12,000 ft., the deteriorating effect of the increased sunlight caused the rubber cable jacket to "sunburn" and fail within a few months. Cure was to substitute a sun-resistant synthetic rubber with abrasion resistance equal to that of natural rubber.

PRODUCT ENGINEERING will pay a minimum of $3 for each example published in Causes and Cures. Where illustrations are necessary, include drawings, rough sketches or photographs.

WIRING OF MACHINES

Electric Wiring Planned With Mechanical Design

IN 1937 an automotive user of machine tools complained that "when we receive a machine tool, as usually shipped today without wiring, a lot of time and money is always lost in getting it into service. I feel strongly that there is a lot that can be done to give the purchaser of the machine tool a wiring job that is permanent, rigid, trouble free, and presentable in appearance."

Much progress has been made in machine tool wiring just as there had been earlier in automotive design when it was shown practical to include bumpers, spare wheel and tire, windshield wiper, defrosting ducts, ash trays, etc., but not until these one-time luxuries were demanded as necessities.

Machine tool builders and designers of other machinery had been thinking about built-in wiring just as they had been thinking of built-in motors, even before 1937. Probably they were waiting for a demand such as that voiced by the automotive engineer.

The necessity for linking electrical and mechanical thought has been shown in many machine tool plants. It was verified by S. G. Leonard, Fellows Gear Shaper Company, at the 1941 Westinghouse Machine Tool Electrification Forum when he said "cooperation between the mechanical designer and electrical engineer from the beginning or rough conception of a machine, and all during its design, will produce a machine which is better, faster, simpler, and smaller than would perhaps be obtained if the mechanical designer designed his machine and then said to the electrical engineer, 'electrify it'."

What Makes High-Grade Wiring?

"A high-grade wiring job," from the point of view of the motor car company representative, "should be made a rigid conduit one as far as at all possible. Flexible wires or cables should be used even in small wire sizes, with proper terminals and fasteners well located and supported. The wiring should be done with coded or colored wires as this is a great help in 'trouble shooting'. The conduits should be within the frame of the machine wherever possible, even the expense of cored openings in the machine castings for conduit and recessed spaces for push buttons, hinged-door openings for controllers, etc., would not seem to me too great an expense to make a complete machine tool."

Much the same views have been held by other users and builders of machines of all types, as evidenced by the type of wiring which is being done today by leading manufacturers of machines and by the standards being set up by the National Machine Tool Builders' Association in a new code for machine electrification.

The presence of quantities of coolant or even small amounts of lubricating oil is an important consideration in the wiring of most machines on account of their effect on rubber insulation. All machines have many problems in common but there are special problems to be considered as well. Machines used in chemical plants, for example, must have wiring resistant to whatever corrosive elements there may be present, or protected against these agents by suitable conduit, or both.

Variations in the requirements or specifications of the users of machines have made it impractical in many plants to use mass production methods in the wiring of machines. Wiring is commonly done, therefore, by methods similar to house wiring; that is, a wire of required length is cut from a spool as required, lugs or connectors attached, and then installed. While this leaves something to be desired in efficiency, this can be compensated to a large degree by advances in lug design and attachment which eliminate soldering and speed up installation.

Other procedures which avoid haphazardness have been described by R. H. Clark, The Warner & Swasey Company, who pointed out that interference with the work of mechanical assemblers and inspectors as well as loss of time impelled him to draw up specifications for an improved installation scheme. This improved method lowered labor cost, enabled bench sub-assemblies, made possible installation at any point of manufacture after the turret lathe bed was set up for final mechanical assembly, allowed use of interchangeable and standardized parts and permitted "farming out" of work. A complete survey of control apparatus was made to indicate the extent of possible standardization. This close study of installation methods was a profitable experience and produced desirable savings even though mass production methods may not be possible.

Wiring Harness Improves Efficiency

Where standardization of machines and wiring is possible, it has proved practicable to assemble wiring harnesses which can be connected to a machine by less skilled workmen. One manufacturer of electrical devices and fittings has gone so far as to offer package units containing all electrical and mechanical devices, mounting brackets, and wiring assemblies for certain types of equipment. A large manufacturer of machine tools makes their own harness, using a braiding machine to wrap and tie the bundles of wires together.

The use of wiring harness has the advantage of improving efficiency by speeding up wiring and requiring less skill for installation. It shows to greatest advantage where a large number of a given style of harness can be assembled at one time. Wire used in a harness may be of any type suitable for a given installation.

Sundstrand Machine Tool Company reports using several harnesses for one machine. By splitting the harness into several units, the pushbutton station, limit switches and other parts can be wired at the bench instead of on the machine, thereby reducing the time the electricians have to tie up the machine on the assembly floor.

Oil-Resistant Insulation

A half dozen machine tool builders who were questioned on their methods of wiring were found to be using wire covered with what is known chemically as plasticized polyvinyl chloride insulation. This insulation is now furnished by a number of manufacturers under several trade names. These include Flamenol by General Electric Company, Koroseal by Goodrich Rubber Company, Gencaseal by General Cable Company, Habirdur by Habirshaw Cable & Wire Company, Densheath by Anaconda Wire & Cable Company, and Okosheath by The Okonite Company.

This type of wire and insulation has won a wide acceptance because its re-

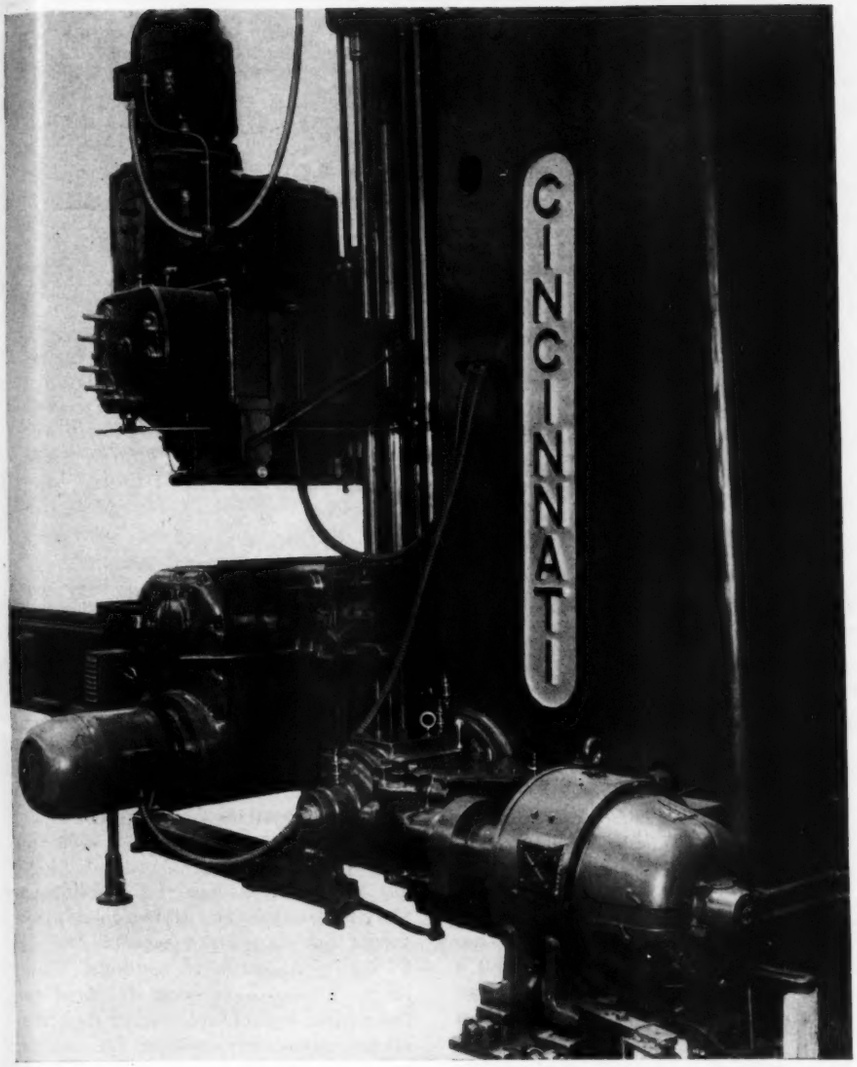


Fig. 1—Extensive use is made of flexible conduit connections to moving parts of the Cincinnati Hypro planer type miller. Movable controls, not shown, are designed into machine by swiveling counterweighted rigid conduit carrying wiring and small control strip around a vertical center post above the machine

sistance to oil is far superior to even the best natural rubber insulation.

Two special advantages of "synthetic rubber" insulation have been pointed out by machine tool electrical engineers. One is that the cable is smaller in diameter for a given wire size, which permits either smaller conduit or more wires in a given size of conduit. The second is the fact that it is easier to pull through conduit because of its slick surface. Although the higher cost of the thermoplastic covered cable might be considered a disadvantage, one user reported that he is able to hold the overall cost with the synthetic insulated wire to the same level as when using rubber insulated wire because of reductions in labor cost attributed to easier handling and the smaller sizes of the cable.

Rubber insulated wire is still being used on some machine tools where wiring is relatively easy to protect against splashing oil by running it through tight or sealed conduit, although machine tool engineers generally agree that oil-resisting insulation should be used. In some other types of machines also, no necessity for changing from rubber insulation has been felt.

Synthetic Rubber Insulation

Some engineers have preferred to change to the so-called synthetic rubbers, Neoprene or Thiokol insulation, both of which have greater oil resistance than natural rubber. Their objection to the polyvinyl chloride type of insulating material is based on its characteristics at high and low temperatures.

Polyvinyl chloride insulation is brittle at low temperatures and has a degree of cold flow which limits its use at higher than normal temperatures. One manufacturer warns against bending wire so insulated at temperatures below —10 deg. C. (14 deg. F.) and against using the cable where temperatures may rise above 176 deg. F., or 140 deg. F. if exposed to oil. Not all of these thermoplastic insulations are identical in physical properties, laboratory tests show, some being satisfactory at lower temperatures than others. The cold flow properties should be taken into account in installing the wire where it goes around corners, particularly in conduit. As explained by one investigator, although the rate of cold flow of the material may be extremely slow, there is a possibility that pressure against corners will break through the insulation eventually and cause a short circuit. Possible development of trouble of this kind can be avoided by keeping wiring loose in the conduit and by filing off corners, or by using round edge bushings or loom at these points.

Since so much of this synthetic is used it is of interest to point out some other favorable qualities. Its tough structure has made unnecessary a protective covering of metal braid, lead, or armor except where mechanical abuse is extremely severe. Manufacturers point out that stripping the ends of the wire is easier on this account. In addition to resistance to oil, synthetic insulation also is stable in the presence of ozone, sunlight and oxygen, and chemicals of an oxidizing nature, and is not attacked by solvents, nor by acids and alkalies. It is also flame-resisting in the sense that it will not support combustion. It is, of course, highly resistant to moisture, and because of its smooth surface dirt does not adhere to it. Unlike rubber, it is available in a variety of colors.

Some lead cable is being used, particularly for runs within a machine where it is not exposed to mechanical injury. Use of lead-covered cable avoids both the danger of oil or acid attack which is present when rubber is used and also the heat damage sometimes experienced with varnished cambric. Where it is desired for extensive inside runs it can be run through rigid conduit on the outside. Even conduit, however, and especially thin-walled conduit, is not completely immune from possible damage if improperly installed. It should be kept close to the outside of the machine so that no protruding ends, elbows or loops invite injury or damage. Long lengths should be held with clips or clamps attached to the machine. On small machines, however, rigid conduit generally does not need support except at the end points where entering connection boxes, according to one authority. On large machines the common practice is said to be to run rigid con-

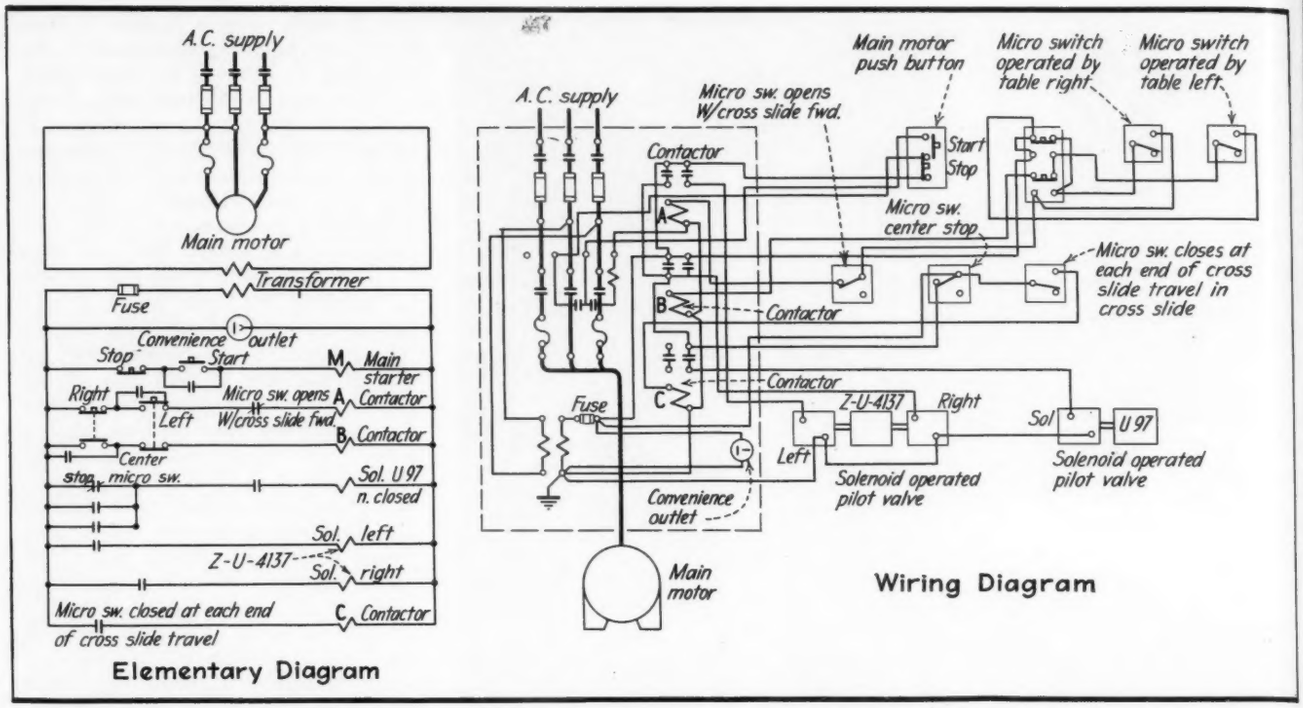


Fig. 2—Diagrams for wiring used by Heald Machine Company on the 49 Boromatic. Machine cycle diagram is also used

duit parallel to the machine base and close to the floor. With this type of installation the conduit may be blocked up from the floor for support if desired.

Wiring Practice

A number of wiring practices have come into use through trial and error methods and the experience of the electrical industry. Of course, it is necessary to have a wiring diagram of the machine such as the one shown herewith but in order to visualize the design requirements or modifications which should be taken into account in designing or redesigning a machine, at least one engineering department superimposes a complete wiring diagram on a skeleton outline of a machine and has found this helpful. This practice was reported by D. K. Frost, Matteson Machine Works.

The ordinary rigid conduit is heavy and stands more abuse than it is often necessary it should. A lighter weight conduit has, therefore, come into use where mechanical protection need not have "brute strength." This thin walled conduit can be bent around corners and made to fit contours of a machine but because of its reduced structural strength is installed usually in less exposed positions. One leading machine tool builder has rejected thin-walled conduit because of the possibility of leakage and bending out of shape. The engineering department finds the cost about the same as heavy conduit and the fittings, like those for flexible conduit, more expensive. Labor, however, was admitted to be more on the heavy conduit. The reference to leakage brings out the fact that this company uses gaskets to seal the conduit connections to junction boxes or fittings.

Conduit fittings which are said to make a water-tight connection to unthreaded thin-walled conduit without a gasket have been developed by one manufacturer of conduit fittings. A bead is put around the conduit near its end by a special tool. A nut then draws on this bead and forces the end of the conduit into a tapered opening where a tight seat is made.

Wiring Moving Parts

For connection to moving parts of a machine, both flexible wire and flexible conduit are used. Wire manufacturers supply wire of several degrees of flexibility dependent upon the number of wire strands and the method of arranging these strands or weaving them. Where flexible conduit must be water or oil tight there are several types of conduit that fulfill this requirement. Duprene hose is used in one instance where liquid-tight conduit is desired. In most such connections it is only necessary to allow a loop of sufficient length to reach the farthest point of movement. In instances where the loop is liable to become tangled or interfere with the operation of the machine it may be suspended by springs or a reel employed to keep the surplus cable wound up. Several manufacturers have developed pay-out reels for this purpose and a wide variety of spring and power wound reels are available. These avoid the danger of exposed power lines for trolleys.

Conduit fittings are of such wide variety that almost any style and requirement that can be conceived can be found by a search of catalogs. While most of these have been designed for the wiring of buildings rather than machines, many are suitable for use on machines. Others that have been developed primarily for machine or industrial use generally offer better protection to the wiring than older fittings, and quicker installation.

The specifications for wiring which one manufacturer has set up include the requirement that "all wiring combinations be made in junction boxes, soldered lugs or equivalent shall be used on all sizes of stranded wires, set-screw forms of contact shall not be used, and all control circuits shall have not less than No. 14 and shall be stranded wire.

"For a.c., all conductors of a circuit shall be placed within one conduit. Wire of different systems shall not occupy the same tubing, unit box, junction box, fitting or cabinet. There shall be no splice or tap within the conduit proper. Cast-in-place raceways shall all terminate in fittings, especially approved for use with them at all junction outlet and switch points. Splices or taps made and insulated by approved methods may be located within gutters if they are accessible by means of

covers or doors. Conductors shall have a minimum carrying capacity of 125 percent of current they are to carry.

"Splicing must at least equal the in sulation of the wire. Rubber coating and friction tape are not enough. Varnished cambric tape shall be used in addition to these. All machines shall be given a breakdown test of twice the voltage of the circuit, plus 1,000 volts.

"All terminals shall be clearly marked for identification, and colored insulated wire shall be used for control circuits, always employing green for start, red for stop, and white for common circuits. Otherwise colors may be used for identification. All machines shall be provided with a terminal lug for No. 8 wire bolted to the machine base for grounding."

It is beyond the scope of this article to discuss the selection of wire size. However, certain restrictions to guide the selection of size have been published by the National Board of Fire Underwriters and other information is available from manufacturers of wire. In general, no wire smaller than No. 14 is approved in a power circuit. Where only electrical resistance and heating tendencies are involved the determination is simple but where there is reactance, particularly where there are several single-conductor circuits close together and magnetic effects to take into account, the determination of suitable wire size becomes more complicated and calls for consultation with competent electrical engineers.

The use of color codes is an individual problem. The availability of synthetic insulated wire in colors has tended to increase the use of color codes in preference to identification by marking tags. Many colors simplify the tracing of wire but make necessary a larger stock of wire than is the case where numbered or lettered tags of one kind or another are attached to wires all of one color. One manufacturer finds there are not enough colors available. Both colors and numbers, therefore, are used for wire identification.

The lack of tapes with properties equivalent to the synthetic insulation has been a handicap in the wiring of machines and has been compared to the weak link of a chain. A synthetic tape is available now which was designed for use with synthetic insulations. It has to be heated after it is applied and the method recommended bv General Electric Company is to apply cellophane over the tape and to use a mold heated to 300-310 deg. F. An alternate method is to apply cellophane, aluminum foil and then an open flame against the foil. A certain degree of skill is required since the time of heating should be just sufficient to flux together the wrapped layers of tape.

There are several other considerations in the wiring of a machine. An important one is provision for extra equipment which may be installed later. It is a simple matter to add extra wiring at negligible extra expense at the time the wiring is done. A second consideration in wiring is safety and provision for automatic safety switches.

The complexity of the electrical circuits of some modern machines emphasizes the increasing importance of long time trouble-free or trouble-proof wiring. The ideal wiring job is one in which the possibility of trouble is made so remote that design effort can be concentrated upon simplicity of installation, compactness and appearance.

Cable Specifications

(Landis Tool Company)

Synthetic thermoplastic jacket and insulation for 19 strand wire (concentric). Cable jacket is 3/64 in. thick for wire sizes up to No. 10 and 1/16 in. thick for No. 8 and larger. Insulation thickness is 1/32 in. for Nos. 14, 12, and 10; 3/64 in. for No. 8, and 1/16 in. for Nos. 6 and 4.

Size A.W.G.	No. Cond.	Jacket Color	Conductor Colors							
			Red	Blue	Yellow	Orange	Purple	Navy	Pink	Brown
14	2	Brown	X	X						
14	3	Black	X	X	X					
14	4	Navy	X	X	X	X				
14	5	Purple	X	X	X	X	X			
14	6	Gray	X	X	X	X	X	X		
14	8	Blue	X	X	X	X	X	X	X	X
12	3	Black	X	X	X					
10	3	Black	X	X	X					
8	3	Black	X	X	X					
6	3	Black	X	X	X					
4	3	Black	X	X	X					
12	4	Navy	X	X	X	X				
10	4	Navy	X	X	X	X				
8	4	Navy	X	X	X	X				
6	4	Navy	X	X	X	X				
4	4	Navy	X	X	X	X				

Single conductor in any size is black.

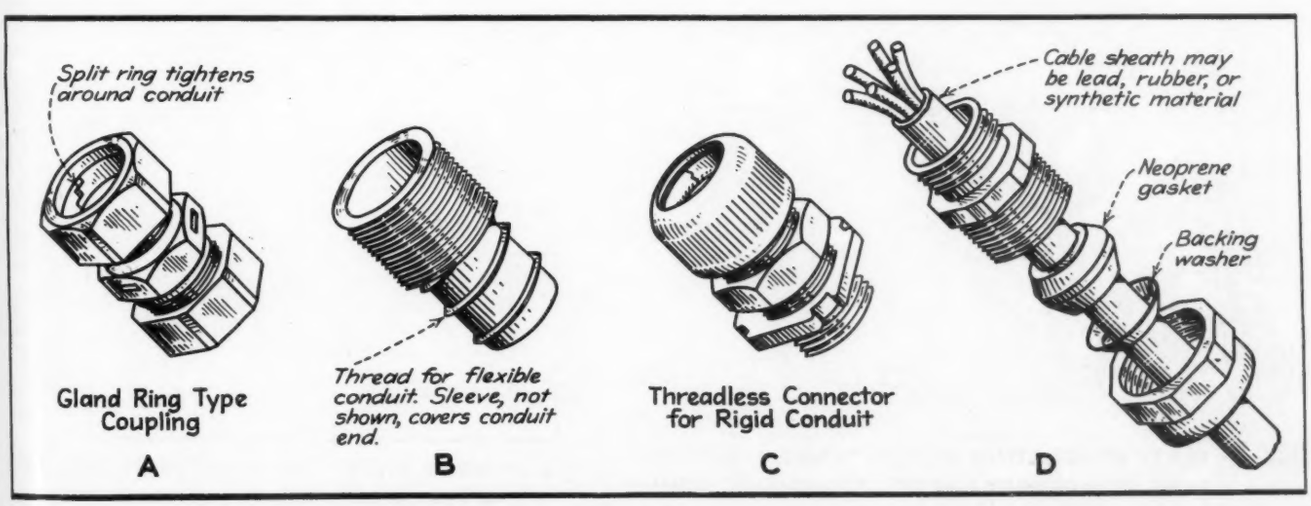


Fig. 3— Four types of conduit fittings recommended by machine designers for making tight joints

INTERMITTENT MOVEMENTS

SEVERAL RECENTLY PATENTED mechanisms for producing intermittent motion are included in this group of devices. Many of the simpler and well-known mechanisms such as the common ratchet and pawl with its many modifications, escapements, numerous variations of the Geneva mechanisms and timed electrical contactors have been intentionally omitted in favor of the more ingenious combinations of mechanisms for accomplishing intermittent motion under unusual conditions.

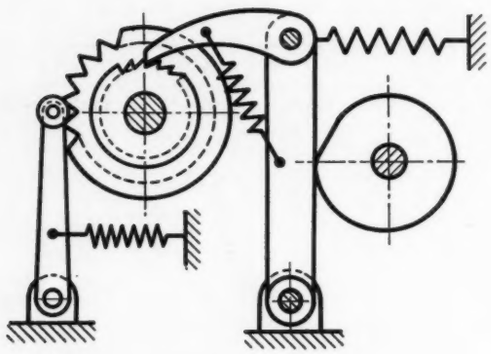


FIG. 1- CAM DRIVEN RATCHET

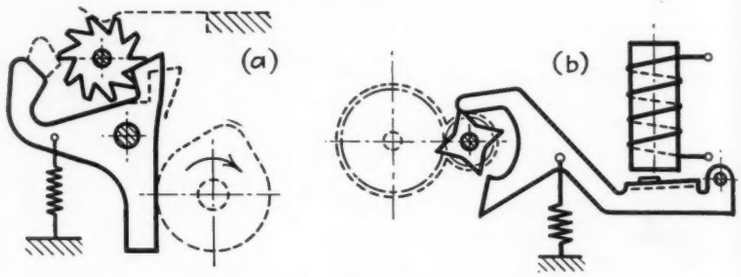


FIG. 3- (a) CAM OPERATED ESCAPEMENT ON A TAXIMETER (b) SOLENOID OPERATED ESCAPEMENT

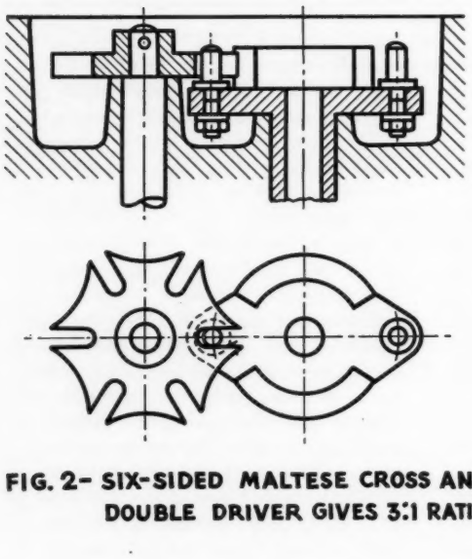


FIG. 2- SIX-SIDED MALTESE CROSS AND DOUBLE DRIVER GIVES 3:1 RATIO

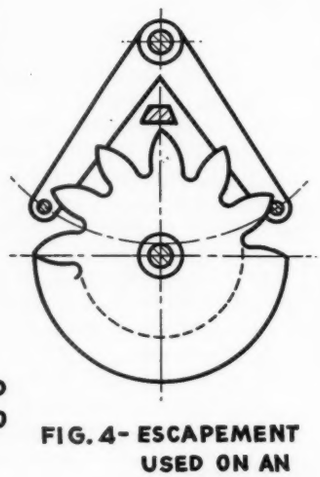


FIG. 4- ESCAPEMENT USED ON AN ELECTRIC METER

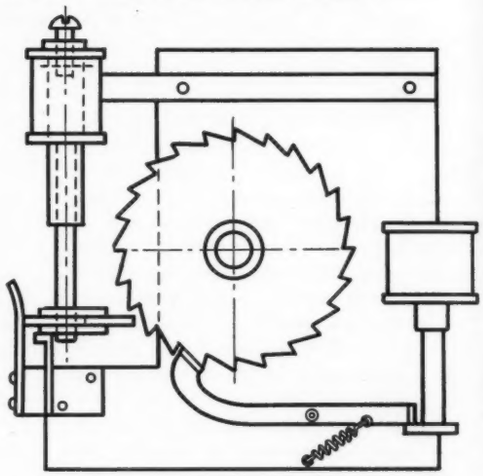


FIG. 5- SOLENOID-OPERATED RATCHET WITH SOLENOID RESETING MECHANISM. A SLIDING WASHER ENGAGES TEETH

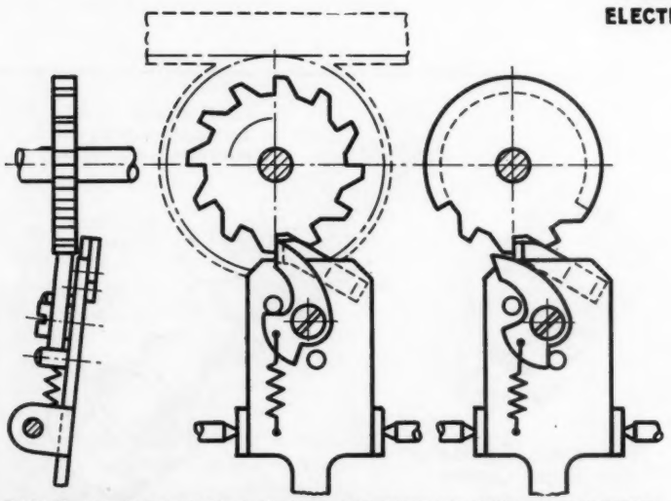


FIG. 6- PLATE OSCILLATING ACROSS PLANE OF RATCHET GEAR ESCAPEMENT CARRIES STATIONARY AND SPRING HELD PAWLS

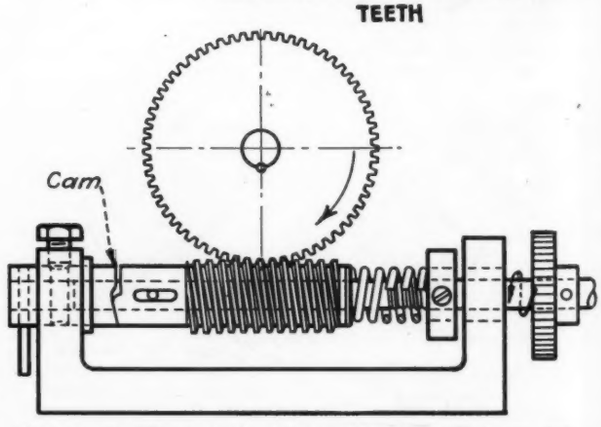


FIG. 7- WORM DRIVE COMPENSATED BY CAM ON WORK SHAFT, PRODUCES INTERMITTENT MOTION OF GEAR

AND MECHANISMS

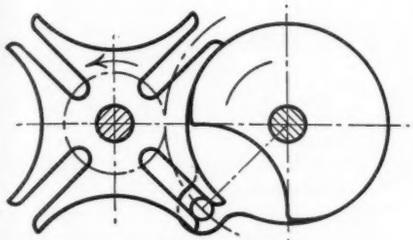


FIG. 8- GENEVA MECHANISM

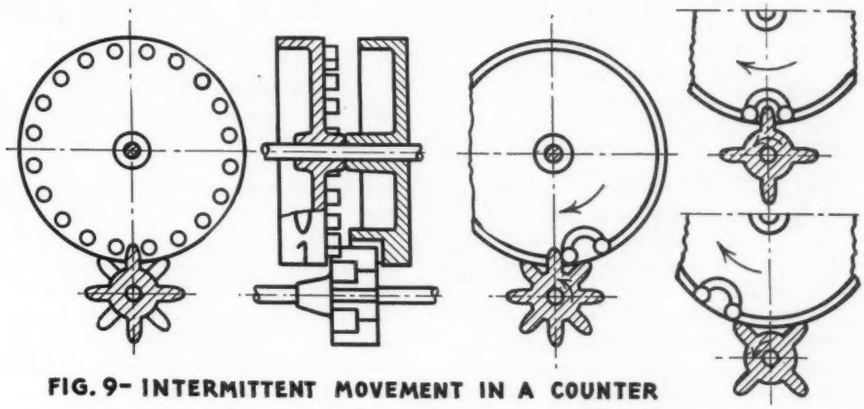
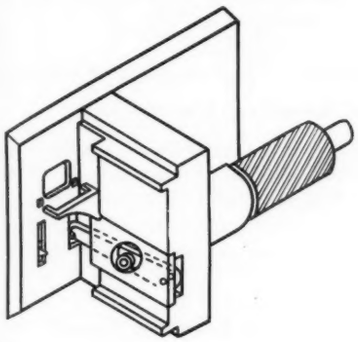
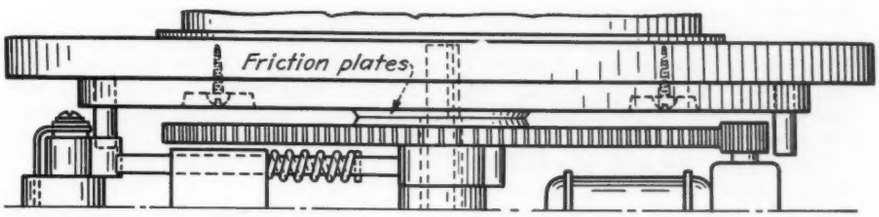


FIG. 9- INTERMITTENT MOVEMENT IN A COUNTER





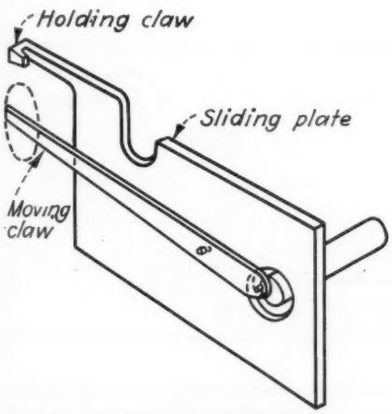


FIG. 10- MOTION PICTURE FILM MOVEMENTS FEATURING SIMPLICITY, FEW OPERATING PARTS, QUIETNESS

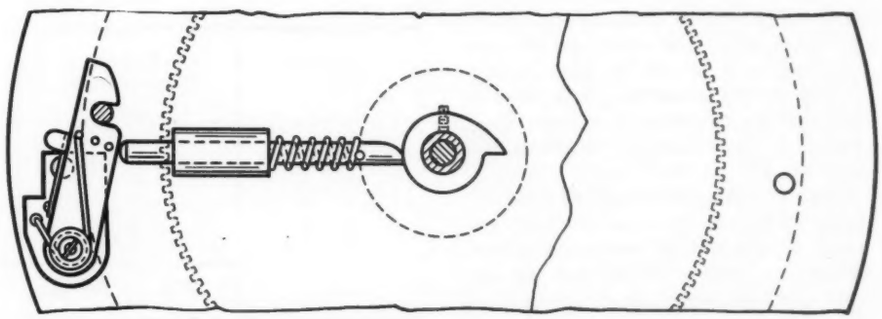


FIG. 11- DISPLAY SIGN MOVEMENT DEPENDS ON FRICTION AND USES A CAM-OPERATED LOCKING MECHANISM. ELECTRICALLY-OPERATED LOCKING MECHANISM HAS ALSO BEEN WORKED OUT BY MEANS OF TIMED-ELECTRIC CONTACTS AND MOTOR-DRIVEN LOCK PARTS

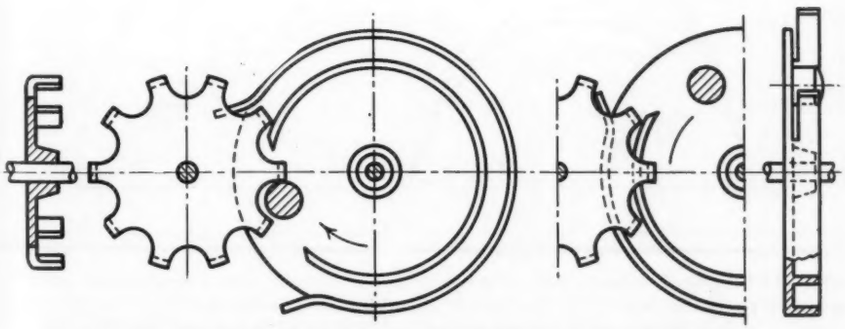


FIG. 12- MODIFICATION OF THE GENEVA MECHANISM

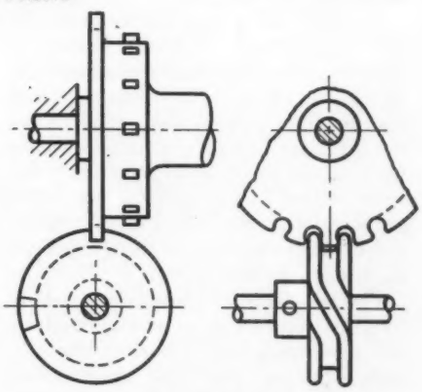


FIG. 13- SIMPLE WORM GEAR MECHANISM

CRANK MECHANISM MOTIONS

New Methods for Their Exact Determination—IV

Dr. WERNER F. VOGEL
Wayne University, Engineering College

NEW METHODS of determining the motion of a central slider-crank mechanism have been presented in this series concluded with this article.

Part I (June *P.E.*) gives a critical review of the approximate principal equations usually applied to the motion of the piston. The inaccuracy of these formulas is shown by error curves which are functions of the connecting rod ratio ($\lambda = r/l$). As a conclusion, a simple construction of an improved approximate curve of acceleration is suggested. This method uses three tangents of the true curve.

Part II (July *P.E.*) introduces a simplified converted form of the exact principal equations, which, for many computations, proves to be even simpler than the approximate principal equations. Details are illustrated in numerical examples. The new form of computation is extended to the angular motion of the connecting rod. Properties and applications of a new "fixed point" of the slider-crank mechanism are revealed.

Two new general graphical constructions of the curve of acceleration (on an exact theoretical basis) are shown, which, contrary to earlier methods, locate the dead center accelerations also. Two other new suggestions deal with the especially simple design of the dead center tangents and the 90-deg. position tangent of the acceleration curve. These tangents make it possible to trace the acceleration curve with greater ease and accuracy.

In Part III (Aug. *P.E.*) distinctive points of the piston's motion curves are discussed. An exact general solution of the maximum velocity, simple enough for practical computation, is given for the first time. Also a graphical construction on this exact basis is shown. The usual approximate formulas for maximum velocity are checked in definite error curves and some of them improved by better approximation.

For the maximum negative acceleration the exact equation and an analysis are developed, and pertinent approximate equations and their error curves are stated. An investigation of the points of inflection gives valuable hints for the shape of the acceleration curve dependent on value of the connecting rod ratio λ.

In Part IV the influence of λ on the form of the piston's motion curves and their critical points is traced in special tables and in numerous graphs. A complete classification of the curves in the possible range $\lambda = 0$ to $\lambda = 1$ is presented here.

The motion of the connecting rod is discussed and simple graphical methods for determining its angular velocity and its angular accelerations are introduced. For the total acceleration of points of the connecting rod a new graphical construction is revealed; it discloses and employs the "pole of acceleration" of the connecting rod.

Since several references are made to tables and illustrations in Parts I, II, and III, it will be convenient to have the June, July, and August *P.E.* at hand while studying Part IV.

Influence of λ on Motion Curves

The Limiting Cases:

The crank mechanism has to be considered between the extreme values $\lambda = 0$ (corresponding to $l = \infty$) and $\lambda = 1$ (isosceles mechanism: $l = r$); at $\lambda > 1$ the crank would oscillate rather

Table XI—Exact Principal Equations of the Extreme Cases

(Simple harmonic motion, see circles in Fig. 39 and straight lines in Fig. 40)
$v = r\omega$ is the crankpin's velocity

Extreme Ratios	Piston Displacement	Piston Velocity	Piston Acceleration
$\lambda = 0$	$x = r\,(1 - \cos\alpha)$	$c = v \sin\alpha$	$a = \frac{v^2}{r} \cdot \cos\alpha$
$\lambda = 1$	$x = 2r\,(1 - \cos\alpha)$	$c = 2v \sin\alpha$	$a = \frac{2v^2}{r} \cdot \cos\alpha$
	For $\alpha \geqq 90°$ note description in text		

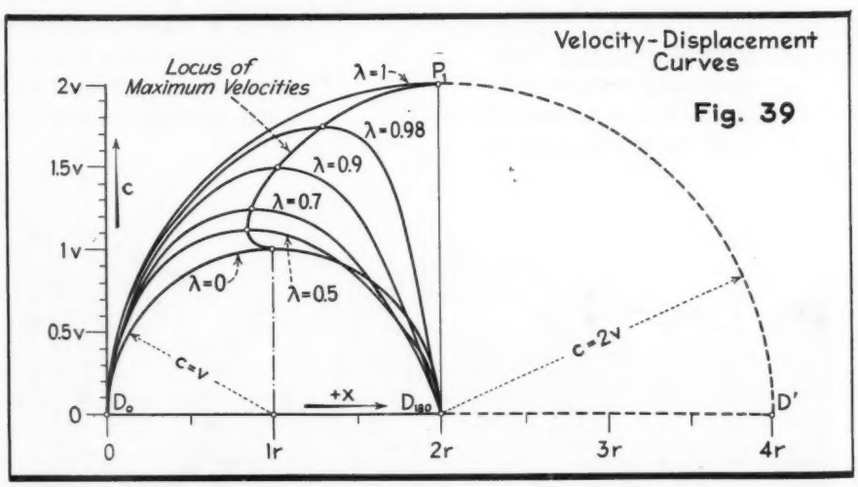


Fig. 39—Curves of velocity for different values of λ; they show semi-circles for the extreme cases $\lambda = 0$ and $\lambda = 1$. Two applications are possible for $\lambda = 1$: The semi-circle D_0P_1D' applies for a double stroke ($s = 4r$) and the curve $D_0P_1D_{180}$ for the usual stroke ($s = 2r$). The ordinates are written as multiples of the crankpin velocity

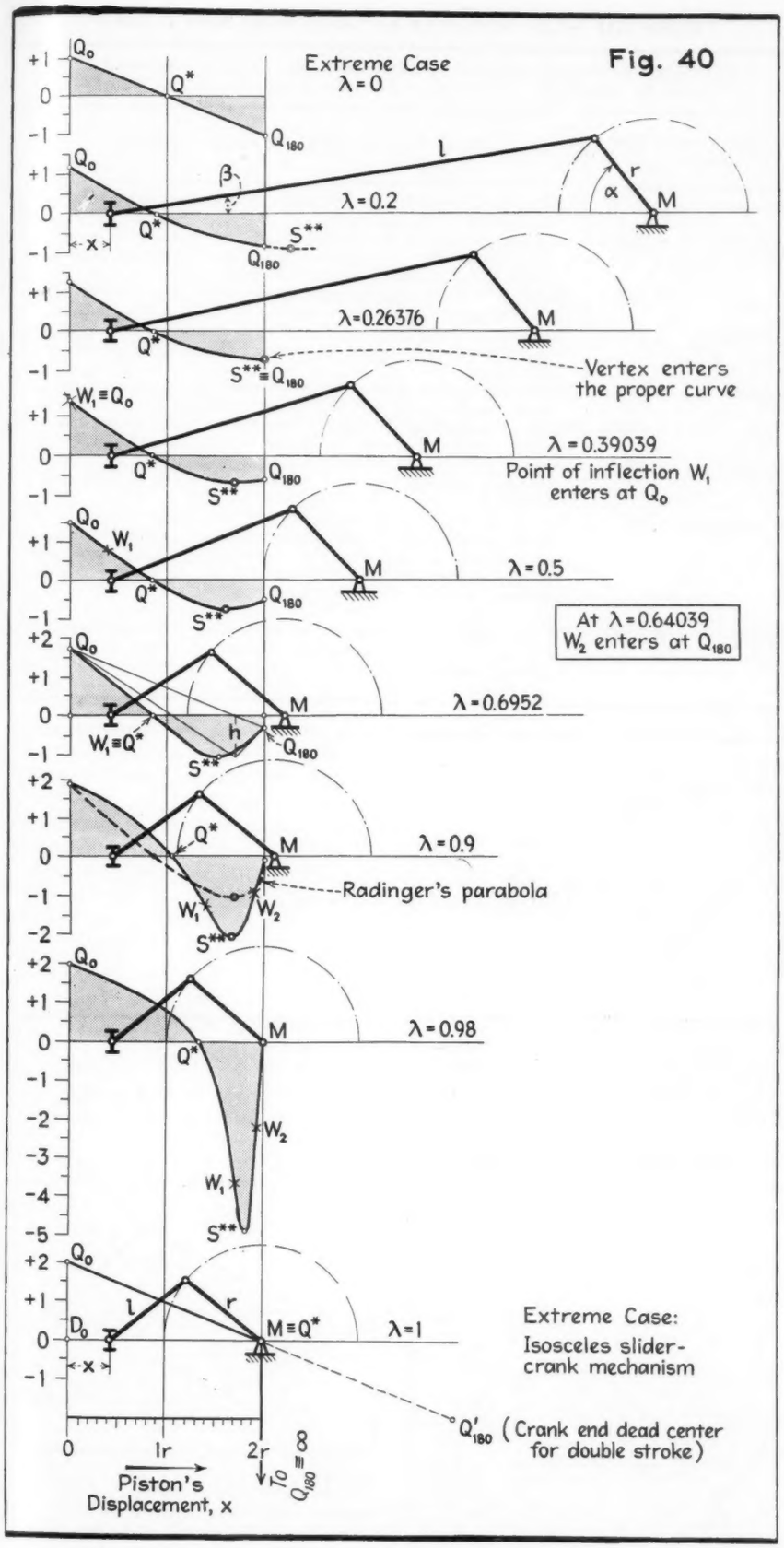


Fig. 40—These curves show the influence of λ on the form of the acceleration curves. The equality of the shaded areas makes the location of Q determine the position of minimum vertex S*. Crosses mark points of inflection as detailed in Tables X and XII. Ordinates give piston acceleration as multiples of crankpin acceleration $r\omega^2$*

than revolve. There are practical applications at both extremes (Ref. 1, June *P.E.*) in which the piston has a simple harmonic motion, represented by the simplified special form of principal equations of motion shown in Table XI. According to these equations the curves plotted against α (or $\omega \cdot t$) are simple sine curves, the velocity curves traced over piston displacements x are circles as shown in Fig. 39 at $\lambda = 0$ and $\lambda = 1$, and the acceleration curves, as shown in Fig. 40 at $\lambda = 0$ and $\lambda = 1$, are straight lines.

However, it should be noted that in the limiting case where $\lambda = 1$ there are two possibilities of motion for the piston:

1. Motion with double stroke, $s = 4r$:

This stroke is possible only when the ratio $\lambda = 1$. The motion curves have the features of simple harmonic motion as indicated by the semi-circle $D_0\ P_1\ D'$ of the velocity curve in Fig. 39 and by the half-dashed straight line $Q_0\ M\ Q'_{180}$ of the acceleration curve in Fig. 40.

2. Motion with usual stroke, $s = 2r$:

The motion is at first the same as that just described, but when the piston reaches $x = 2r$ and has maximum velocity, it has to be braked instantaneously, as indicated by line $D_0\ P_1\ D_{180}$ in Fig. 39, to the velocity $c = 0$ by means of an acceleration $a = -r \cdot \omega^2$ characterized by the line $Q_0\ M\ Q_{180}$ for $\lambda = 1$ in Fig. 40. During the following period the piston's velocity remains zero while the crank continues to revolve (Ref. 3 Part I) with constant angular velocity.

Since the crankpin ordinarily governing the acceleration of the piston cannot accelerate the piston in this position, a sudden stop would necessitate special equipment, which, of course, could only approximate the needed shocklike deceleration. The possibility of practical realization of this motion of an isosceles-crank mechanism with the stroke $s = 2r$ is of theoretical interest, however, because it is the keystone in the complete classification of the motion curves in Figs. 39 and 40.

The influence of λ:

In Fig. 39 the form of the velocity curves is given for different values between $\lambda = 0$ and $\lambda = 1$. The locus of maximum velocity shows the path of the vertex S^* between the extreme circles when λ varies. The analysis for $c_{max.}$ is given in Figs. 21 and 23-27. The alteration of the abscissa x^* of the vertex S^* of velocity may be followed also in Fig. 40 by studying the change of location of the zero-point Q^* of the acceleration curve.

The more important influence of λ on the character of the curve of acceleration

is clearly illustrated in Fig. 40 and in Table XII, which should be considered together. Further details on the vertex S^{**} and points of inflection of this curve are given in the corresponding previous sections.

The $(-a_o)$ line in Fig. 34 allows a comparison between the head dead-center acceleration $a_o = r \cdot \omega^2 (1 + \lambda)$, usually employed in computing strength, and the negative acceleration a^{**}. At extremely high values of λ the negative acceleration can become even greater than head dead-center acceleration.

Design of the Connecting Rod's Motion

The connecting rod has plane motion, composed of the translating motion of the piston and a superposed angular motion.

The angular motion (rotation) of the connecting rod may be expressed either by the equations of Table III, or by Equations (20)—(22) of Table VI. In Fig. 10 a simple graphical design of the angular velocity ω_β of the connecting rod is shown. If a complete motion curve for ω_β is desired, the construction of Fig. 41 is preferable. A simple construction for the angular acceleration ε_β is given in Fig. 42.

The total motion of the connecting rod can be determined by means of the "pole of velocity" and the "pole of acceleration." The pole of velocity, generally known as "instantaneous center," is easily constructed as illustrated in

Table XII—The Influence of Connecting Rod's Ratio

(This influence can be followed by reference to Fig. 40 where acceleration curves for significant values of λ between 0 and 1 are illustrated)

Connecting Rod Ratio λ		Properties of Curve of Acceleration
Equals	0.0000	Curve is a straight line (simple harmonic motion) for this imaginary ratio, as shown by the top diagram of Fig. 40
Less than	0.26376	No vertex occurs in the acceleration curve. The second diagram of Fig. 40 shows the vertex S^{**} on an imaginary extension of the curve when $\lambda = 0.2$
Equals	0.26376	Vertex S^{**} enters the curve from right at Q_{180}, as shown by the third diagram of Fig. 40 at this value of λ.
Less than	0.39039	No point of inflection occurs on acceleration curves until this value of λ. Curves of Fig. 40 are concave downward up to this value.
Equals	0.39039	Point of inflection W_1 enters the acceleration curve from the left at Q_0, as shown by the fourth curve of Fig. 40.
Equals	0.64039	Point of inflection W_2 enters the acceleration curve from the right at Q_{180}. No curve is drawn to illustrate this in Fig. 40.
Equals	0.6952	Point of inflection W_1 coincides with zero point Q^*, as shown by the sixth curve of Fig. 40. The second point of inflection is not shown.
Greater than	0.88	Maximum negative acceleration a^{**}, belonging to vertex S^{**}, is absolutely greater than the usually computed dead center acceleration a_0 (see Fig. 34). This is important for computations of strength. Fig. 40 includes two curves for this condition.
Equals	1.0000	Curve consists of one or two straight lines. (Simple harmonic motion. Isosceles mechanism without or with a range of discontinuation). Bottom diagram of Fig. 40 shows this.

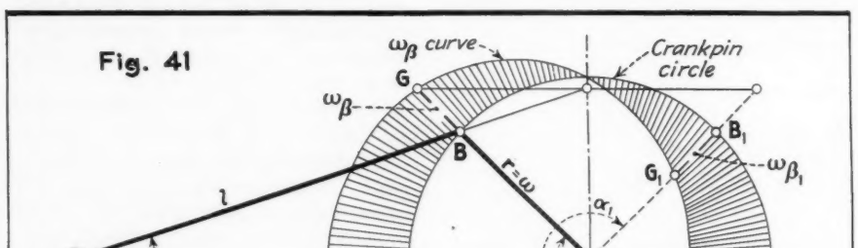


Fig. 41—In this graphical construction for the angular velocity ω_β of the connecting rod, ω_β is represented by the radial distance BG *which is negative (counter-clockwise) if* G *is outside the crankpin circle. The scale of ω_β is given by having the crank equal its angular velocity ω. Conjugate positions B and B_1 of the crank ($\alpha_1 = 180 - \alpha$; $\beta_1 = \beta$; $\omega_{\beta_1} = -\omega_\beta$) are indicated*

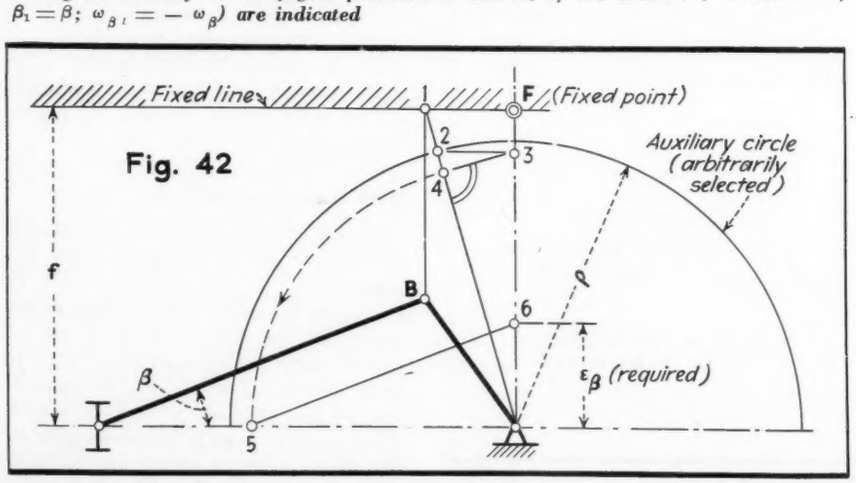


Fig. 42—To determine the angular acceleration ξ_β of the connecting rod, the numbers 1–6 give the sequence of the points of construction. Line 5–6 is parallel to the connecting rod. The radius of the auxiliary circle is arbitrary; the scale of ξ_β is determined by: $\omega^2_{crank} = \rho$

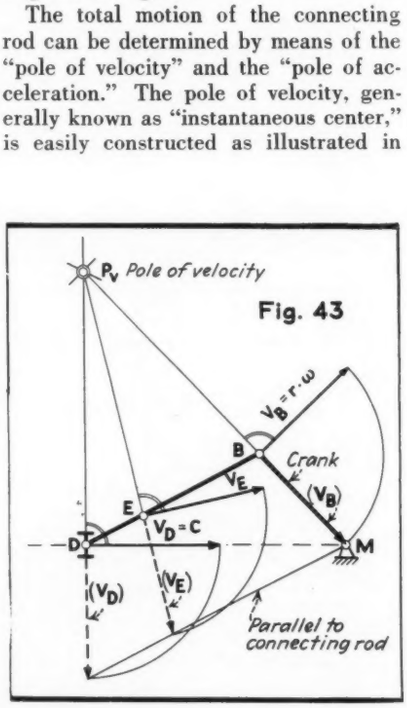


Fig. 43—The pole of velocity of the connecting rod, better known as "Instantaneous Center," determines the magnitude and direction of the velocity of any point on the connecting rod when the angular velocity ω of the crank is known. The magnitude of all velocities is proportional to their distances from the pole

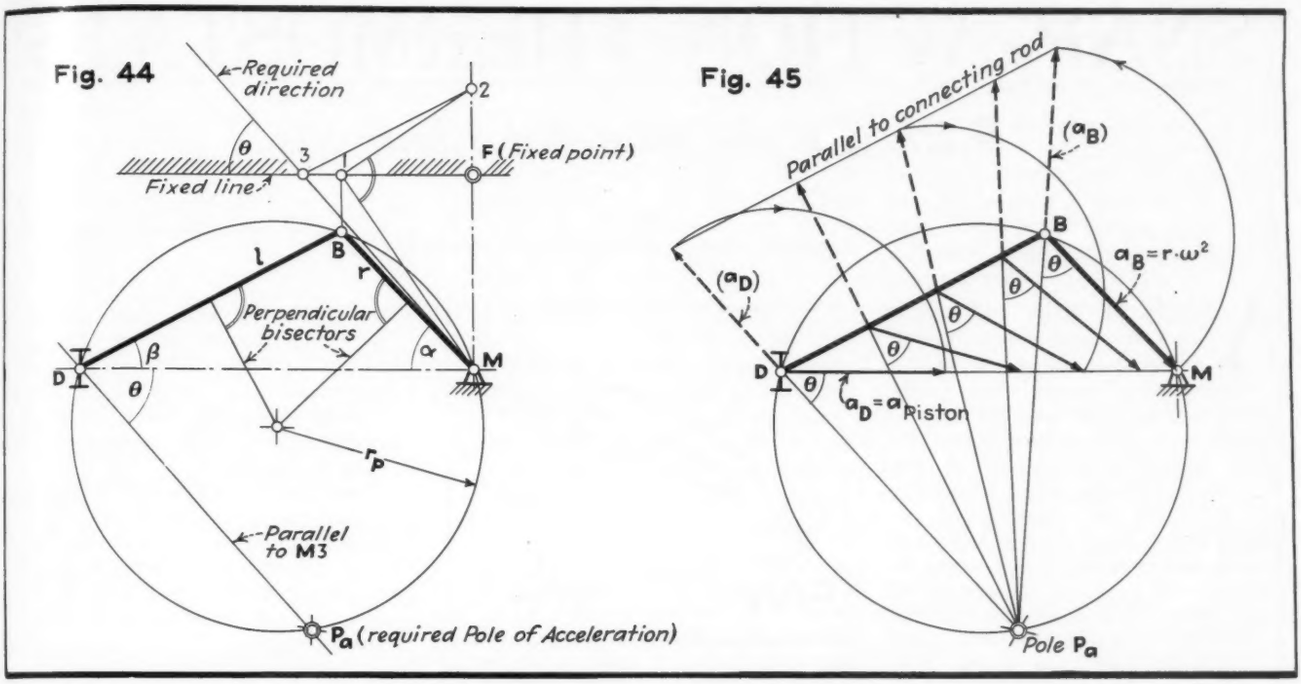


Fig. 44—The pole of acceleration of the connecting rod is located on a circle through M, B, and D whose radius is:

$$r_p = \frac{l}{2 \sin \alpha} = \frac{r}{2 \sin \beta}$$

Basis of construction: $\text{cotan } \theta = \text{cotan}^2 \psi \cdot \text{cotan } \beta$

Fig. 45—The accelerations of all of the points of the connecting rod are proportional to their distances from the pole. The dotted arrows are "turned accelerations" and are correct only in magnitude. The solid vectors of acceleration are correct also in direction. The heads of all vectors are located on the straight line DM

Fig. 43. The purpose is to show its location and application in comparison to that of the "pole of acceleration."

In engineering circles the pole of acceleration is little known, probably because there is no simple general method for its construction. For the slider-crank mechanism, on the contrary, a simple way to find this pole is revealed in Fig. 44. The procedure employs the new fixed point *F* shown in Figs. 10-12. The application of the pole of acceleration for the design of the acceleration *a* of the piston as well as that of every point of the connecting rod's axis *BD* is shown in Fig. 45. However, it is worthwhile to note that the utilization of both of the poles is not confined to points of the axis, but is rather applicable to any point of the connecting rod.

Often the acceleration of the piston is already known either by computation, or from the acceleration curve given in Parts I and II. In this event a complete diagram of the accelerations of points of the connecting rod can be easily traced without previous knowledge of angle θ. The simple construction shown in Fig. 46 is of particular value for the dead centers and neighboring positions of the mechanism, in which the pole of acceleration is too far from the mechanism for practical utilization.

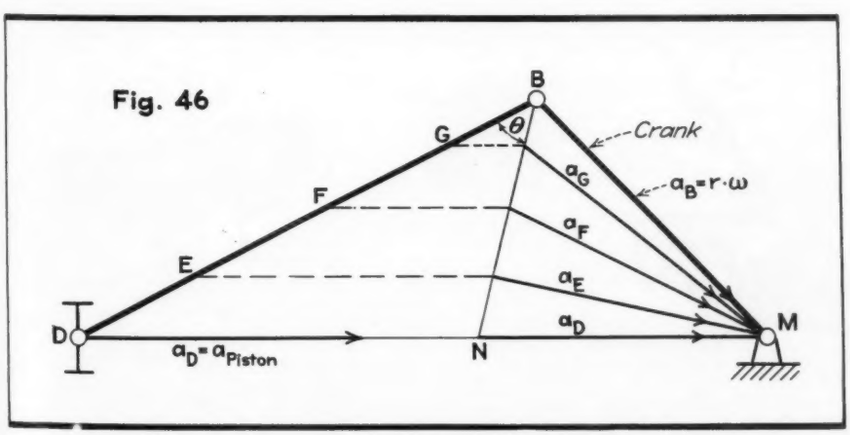


Fig. 46—Construction for determining acceleration of connecting rod parts without using the pole. The required magnitude and direction of accelerations of the connecting rod's points D, E, F' and G are found in vector diagram BNM

Editor's Note: The following corrections are to be noted in Parts I to III, published in June, July and August issues of PRODUCT ENGINEERING. In Table II, p. 301 the equation-number 2 should be indicated in the proper place. In Fig. 3, p. 303, the equation for dead end dead center acceleration should have a plus sign instead of a minus sign:

$$a_0 = r\,\omega^2\,(1 + \lambda)$$

In Equation (10), p. 374, ξ_2 should be ξ^2 and an independent quantity under the radical sign. Thus:

$$c = \omega \sqrt{\frac{4\xi^4 l^2}{(\xi^2 + f^2)^2} - \xi^2}$$

In Fig. 20, p. 423, the shaded area below the horizontal center line should include the area between the dead center tangent, Q_0H, and the acceleration curve, $Q^*—Q_\infty$ (approximately).

On p. 428, last column, first line, ξ_∞ should be ξ_{w_1}. On p. 428, last column, last sentence, the reference should be to Table XII instead of Table XI.

SNAP-ACTION THERMOSTATS

With Simple Bimetal Elements

P. R. LEE
Westinghouse Electric & Manufacturing Company

A GOOD THERMOSTAT should have few parts, small overall dimensions, and should be easy to manufacture. It should control temperature closely, should have positive snap-acting contact, freedom from radio interference, long life, and good temperature stability for many years. The simple snap action bimetal strip described in this article gives a thermostat control with these desired characteristics. In order to reduce the number of parts and overall dimensions of the thermostat, this element can be designed as the switch itself, carrying the contacts with it.

Construction and operation of the bimetal strip designed to give snap action can be understood by reference to Fig. 1. In Fig. 1(a) is shown the rectangular piece of bimetal with two longitudinal slots and the outer strips crimped. The crimping has the effect of making the two outer strips act in the manner of coil springs under tension, thereby putting the center strip under compression, *P*. This force *P* or moment *Pe* always resists straightening of the bimetal and is balanced by the resisting moment developed over the cross-section of the strip plus the bending moment created by the more rapid expansion of the metal on the concave face of the strip when the temperature rises. At a certain temperature the strip begins to straighten, *e* decreases, bending moment *Pe* decreases, and there is an increasingly unbalanced moment that finally causes the bimetal to straighten and then reverse with a snap action from concave to convex. Upon cooling the bimetal snaps back again in a similar manner.

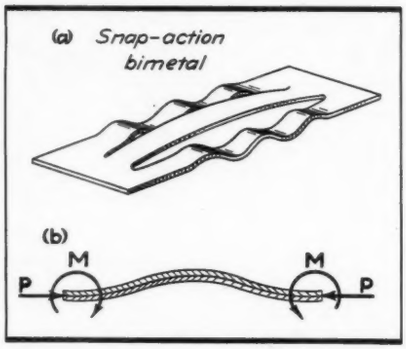


Fig. 1—These sketches show principle of snap-action of bimetal thermostat

There are many different methods for mounting this element into a thermostat, each method giving slightly different results. Seven such methods and their advantages are described on the page opposite. In Fig. 2 are illustrated three completely assembled thermostats.

Accuracy of the temperature at which the thermostat operates depends primarily upon the manufacturing control. Large quantities of these elements can be manufactured with few temperature rejects, once the proper size, initial curvature, crimping, and heat-treatment are determined by laboratory tests and set up in production.

Temperature differentials depend on physical dimensions of the link and on whether the thermostat is of the fixed or the adjustable temperature type. If fixed, differentials as low as 2 deg. F. are possible. If adjustable within a temperature range of approximately 300 deg. F., differentials as low as 10 deg. F. are possible. Adjustable thermostats maintain a constant temperature calibration for at least 250,000 cycles. For most applications this represents a life of many years.

Application requirements and economy determine the size of the bimetal element to be used. The smallest size made thus far is ½ in. long, and has successfully interrupted a 40-amp. a.c. resistance load at 115 volts at a speed of one cycle per second.

In the assembled thermostat shown in Fig. 2(a) the bimetal unit weighs 1/10 oz. and is about 2 in. long. This unit exerts a pressure of 5 lb. on the contacts. High contact pressures insure freedom from radio static because there cannot be any fluttering, usually caused by low pressure or dust particles.

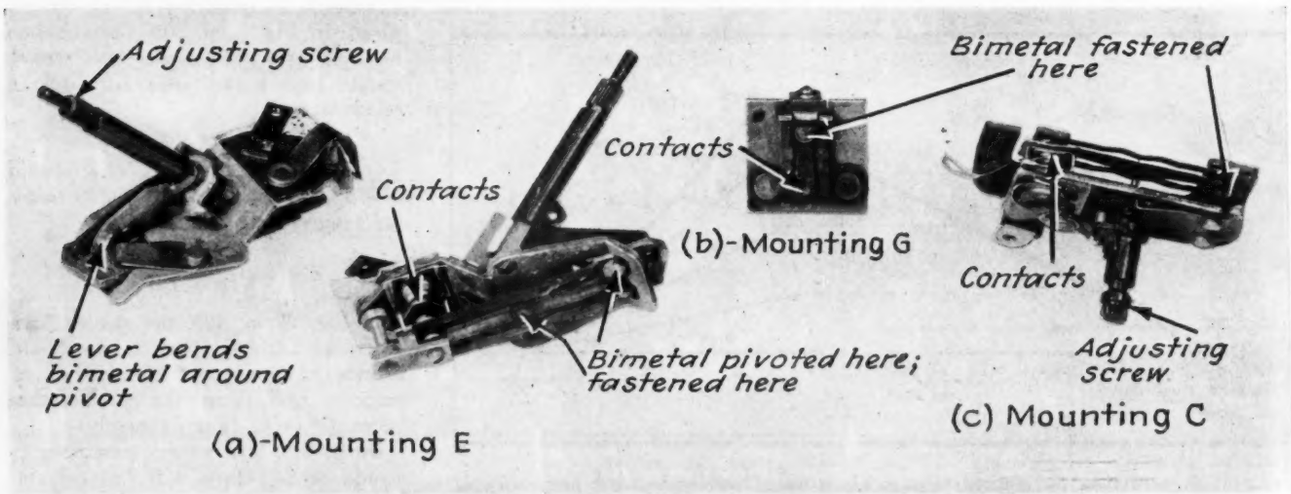
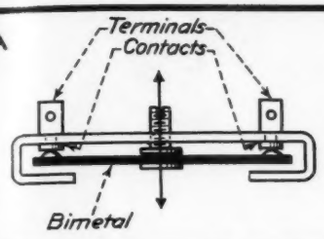
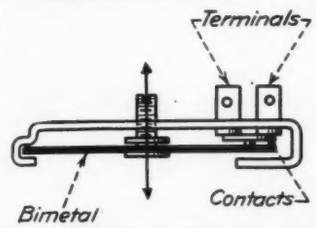
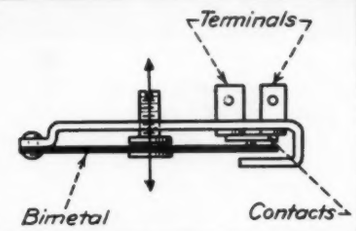
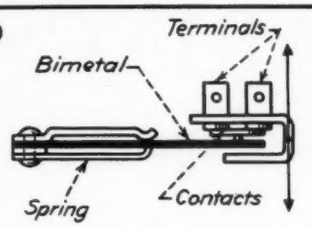
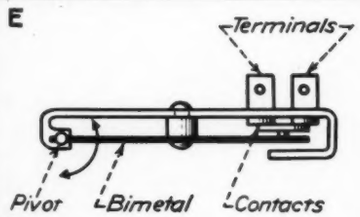
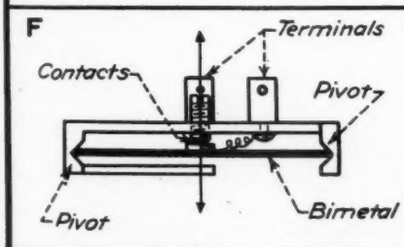
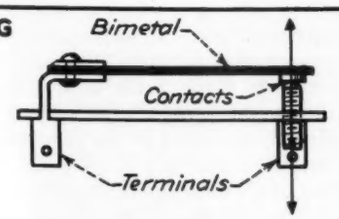
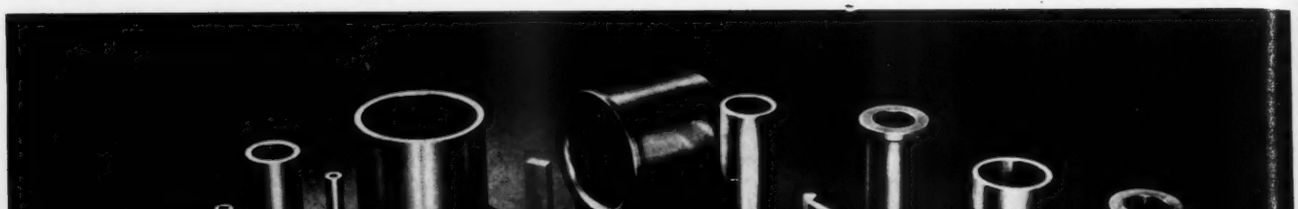


Fig. 2—Three assembled thermostats with simple bimetal snap-action elements, mounted by methods shown opposite

Methods for Mounting Bimetal In Thermostats

A 	*(A) For adjusting temperatures, center support is moved up and down. Advantages: (1) uniform closing temperature; (2) high interrupting capacity; (3) bimetal can be used as a current-limiting device; (4) any current from 10 to 200 amp. depending on size, length and type of inclosure. Disadvantages: inherently wide temperature differential. Application: non-adjusting thermostat where an accurately adjustable temperature setting is required, as in water heaters, flat irons and glue pots.*
B 	*(B) Contacts at one end only with the midpoint of the bimetal held stationary. The other end of the bimetal pivots freely thereby giving the bimetal freedom to act. Temperature adjustments are accomplished in the same manner as (A) above. This method gives closer temperature differential than (A), but responds less uniformly to the temperature settings because of larger tolerance on closing temperature. It would be used on the same kinds of devices suggested for type (A) thermostats.*
C 	*(C) Contacts at one end of the bimetal; midpoint is stationary. The other end of the bimetal is rigidly anchored to the frame. Temperature adjustments are made by moving the center support in the same manner as in (A). Lost motion is eliminated at the left end of the bimetal, which is fixed. This gives closer temperature differential than (B), but temperature differential settings are less uniform. Applications would be about the same as for (A) and (B).*
D 	*(D) One end of the bimetal rigidly anchored to the base structure. The midpoint is allowed to pivot about a fixed point. Midpoint of the bimetal is held against the base by a spring. The other end carries contacts, the positions of which are adjustable. To obtain temperature adjustment, contact structures are moved up and down. There is no lost motion in the bimetal structure; temperature setting is less erratic. It costs slightly more than type (C) and its applications are the same.*
E 	*(E) Contacts mounted on one end of the bimetal. Midpoint of the unit is rigidly anchored to the base. The other end of the bimetal is allowed to pivot about a fixed point. Temperature adjustments are made by rotating the fixed end of the bimetal about this pivot. This type of unit has narrow temperature differential, positive snap action, and long life, but it costs more than some of the others. It can be used on flat irons, water heaters, and as a room temperature control.*
F 	*(F) Both ends of the bimetal placed in fixed pivots. Contacts are placed at the midpoint of the bimetal and, for obtaining adjustments in temperature, these center contacts are moved up and down. Contact structure is inexpensive, is free from creeping action at the contacts, and contact pressure is high. The pigtail may interfere somewhat with the snap-action. It could be used for any device requiring only non-adjustable settings, such as a glue pot or sterilizer.*
G 	*(G) Contacts placed on one end of the bimetal. Other end of the center strip is rigidly anchored to the base structure. To adjust temperatures, end-contact structure is moved up and down. Advantages are low cost; close temperature differential if it is used as a non-adjustable thermostat; good temperature stability; and it will snap on any current from 10 to 200 amp. Life of this unit is relatively short. It would be good for motor protection or current-overload protective devices.*



Bound Brook Oil-Less Bearing Company

A wide variety of shapes and sizes of bearings and parts can be made from powdered bronze and powdered iron

POROUS METAL BEARINGS

Methods of Design and Discussion of Properties

A WIDE RANGE of bearing service requirements can be met by the variety of porosities and compositions which manufacturers of porous self-lubricating bearings are producing. The majority of applications require no special engineering nor precautions but in borderline applications where failures are most liable to occur the recommendations of the bearing specialist should be obtained and followed. Selection of the right bearing for such service cannot be made from a handbook, according to an engineer of one of the leading manufacturers of these bearings, since there are so many variables present in the testing or operation of any bearing that definite specifications regarding loads, speeds, clearances, etc., are impossible. In addition there are other considerations such as composition, hardness and methods of surface finishing of the journals, methods of lubrication, operating temperatures, and other factors.

The term "borderline applications" as used above indicates a vague area between successful applications of porous bronze and of cast bronze bearing materials, rather than a definite boundary line. There are certain applications where only cast bronze or other solid bearing materials have been able to serve, such as crank shaft and connecting rod bearings. "It is true also," says R. P. Koehring, Moraine Products Division, General Motors Corporation, "that heavy shock loadings usually require solid bearing materials. Where medium to high speeds are encountered with fairly balanced loads, self-lubricating bearings have proved superior to cast bronze. There are also a great many applications where these bearings and cast bronze have proved equally satisfactory."

In general, self-lubricating bronze bearings are not recommended where bearings are subjected to extreme impact and high pressures. However, W. G. Calkins, Chrysler Corporation, states that their self-lubricating bearings "function perfectly in our steering gear trunnion shafts and have been used at this point for years. Here they are subjected to extreme impact and high pressures. On extremely accelerated laboratory tests, the housings, worms, and shafts will fail without damage to bearings." He added that "the use of uncoated or unimpregnated sintered bronze bearings for connecting rods must be predicated on use in conjunction with hardened crankshafts which at present are not in production on any passenger car engines. If impregnated with tin base or lead base bearing material as lead, tin, or cadmium it is possible to run these bearings with conventional heat treated crankshaft of around 250 Brinnell hardness with satisfactory results."

Improvement in manufacturing methods and bearing design, accompanied by volume production, have lowered bearing costs as well as improved their quality and service characteristics. The rapidity of progress in the industry is emphasized by one manufacturer by the statement that its "bearings today are superior to those made a year ago." Evidence that progress is still being made may be found in the growing use of powdered iron as a bearing material.

One of the most significant statements made by the manufacturers of these bearings is that standard design prac-

tice for solid bronze bearings may be used for sintered bronze bearings. Changes in design are on the side of simplification rather than complication. For example, oil grooves, oil holes, oil cups and any other details involved in feeding oil to bearings are eliminated.

One way to avoid bearing trouble in using the porous metal bearing for the first time is to submit the following information to the manufacturer for his recommendations:

1. Receiving hole diameter
2. Shaft size, type and finish
3. Shaft speed (r.p.m.)
4. Temperature of operation
5. Type of lubrication (flood, oilless, etc.)
6. Bearing load (lb.)
7. Type load (intermittent, steady, etc.)
8. Type service (constant, intermittent, short or long run, etc.)

Self-lubricating bearings are not confined merely to applications where they hold sufficient lubricant to last the life of the machine in which they are used, nor is it required that the pores in the bearings be the total reservoir when a bearing is required for such service. An additional reservoir of oil can be provided by coring or machining cavities in the bearing housing. Usually these cored reservoirs are packed with wool waste to hold the oil and to serve as a wick to supply the bearing with oil as required. Typical examples of installations utilizing oil reserves in this manner are shown in the accompanying illustrations. By means of a drilled hole or slot the oil may be brought to the outer surface of the bearing where it will be absorbed into the bearing by capillary action. Oil would be supplied by an oil can or oil cup, as in other types of bearings.

Assurance of a continuous supply of oil to maintain a lubricating film on the bearing is important to freedom from lubricating difficulties. Any tendency of the bearing to heat is counteracted by expansion of the oil contained within the pores of the bearing, which generally constitute 25 to 35 percent of its volume but may be more or less than this. The oil flows out on the bearing surface and replenishes the lubricant film. One manufacturer has standardized three porosities classified as follows:

1. High porosity (25-35 percent), for high speeds and light loads
2. Standard porosity (18-25 percent), for general purpose applications
3. Low porosity (10-18 percent), for low speeds and medium to heavy loads. For intermittent operation and for slow oscillating and reciprocating motion.

The pore openings in the bearing surface are no more visible than the pores in the skin but hydraulic pressure or heat will bring oil to the mirror-like surface like skin perspiration on a hot humid day. It should be noted here that the bearing structure can and does take over the function of grease in holding lubricant in readiness for service and does away with the messiness of grease.

A second advantage pointed out by Dr. Carl Claus, Bound Brook Oil-Less Bearing Company, is the fact that metal powders used in making bearings are of high purity and remain so during the manufacturing process since they are exposed to oxidizing temperatures only in a controlled atmospheric furnace. Blow holes and other possible casting defects are avoided. Uniformity of structure of porous bearings is assured by predetermining weight and dimensions.

Any changes in dimensions of a bearing resulting from the sintering operation are corrected by a sizing operation in which the bearing is again compressed. This sizing operation gives the bearing surface its mirror-like finish, which it retains after installation, and an accuracy which is said to enable greatly decreased bearing clearances and resultant improvement in quietness of operation.

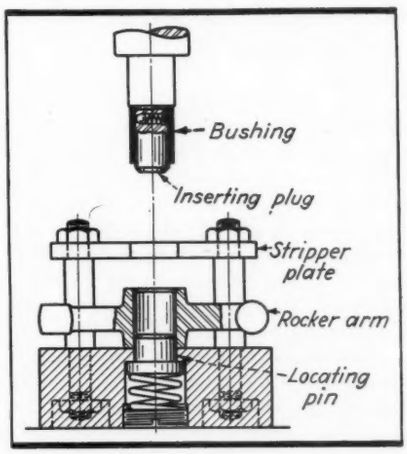


Fig. 1—Production fixture for inserting a bearing into a rocker arm. The rocker arm is aligned with an inserting plug by a locating pin which is displaced by the bearing when it is pressed into place. The stripper plate releases the rocker arm from the inserting plug on the upward stroke of the press. Various other devices have also been worked out

Installation Method Important

The method of installing the bearing is important to the satisfactory operation of the bearing. These bearings can be mounted with closer clearances than are possible with cast and machined bearings, and by cost-saving methods not applicable to other bearings. A hardened steel plug is used to maintain bore size and alignment in a simple press operation requiring no skilled operators, nor expensive tools. This plug is ground to 0.0002 in. over the minimum bore diameter desired after installation. The diameters of the bearing are generally dimensioned 0.003-0.004 in. over the housing and shaft sizes. Pressing into the housing closes in the bore without affecting the finish produced by the sintering and repressing operations, it is said, and brings the bearing to the desired bore size around the inserting plug. For this operation the plug is rigidly supported to hold it concentric with the housing, so that regardless of any eccentricity of the bored holes for the bearing, the shaft will fit properly in line even if the axial alignment of the bored hole should be out 0.0008 in. for any reason.

Reaming is not only unnecessary but is undesirable. It destroys the porosity at the surface of the bearing and also the mirror-like finish, and does not make a true cylindrical hole since it removed only the high spots on the bearing surface.

When necessary to size the bore a maximum of 0.005 in. or to obtain graduated bore sizes for selective manufacturing, special burnishing tools are recommended. Burnishing tools are of high speed steel with a hardness of Rockwell C60-62. Successive buttons on such a tool may increase in diameter by 0.0005-in. increments.

While porous bronze bearings may be machined, this is discouraged by manufacturers of these bearings. Machining by methods used on cast bronze seriously impairs the self-lubricating properties of the surface machined. When machining is necessary a "dead sharp, pointed shaped tool (1/64 in. radius) of diamond or tungsten carbide" is recommended, taking "a very light cut, 0.002 to 0.004 in. on the diameter, with a fine feed and high speed." After machining, the bearing is soaked in a crankcase lubricating oil of good stability with respect to oxidation. The viscosity is usually S.A.E. 30. For quick impregnation, the oil is heated to 140 deg. F. and the bearing submerged 15 minutes. Oil may be removed when desired by immersion in such solvents as clean gasoline, carbon tetrachloride, ether, or alcohol.

"If through error in machining, the porosity of a bearing is impaired," the engineering department of Chrysler Corporation has found that "the bearings can be restored by immersion in a bath of 50 percent nitric acid and 50 percent water for about 30 sec." This acid treatment changes the bearing diameters by

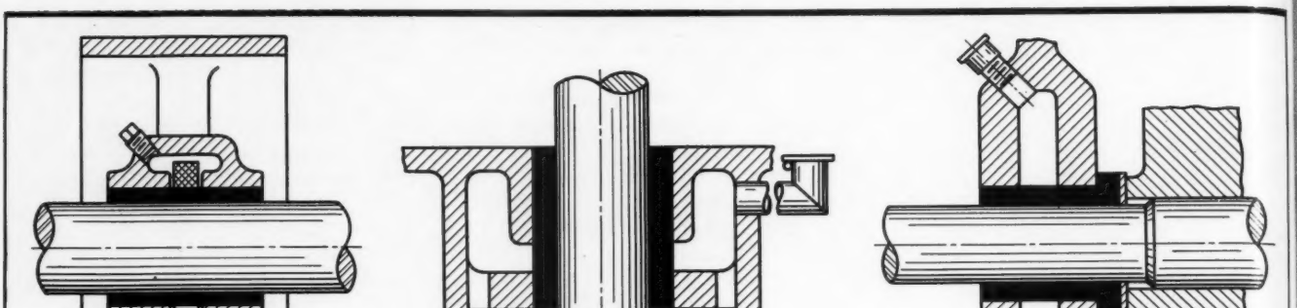


Fig. 3—Examples of lubrication of self-lubricating bearings. (a) A felt ring in the annular recess and in contact with the bearing acts as an oil wick. (b) Bushing and thrust washer get lubricant from an oil cup. (c) A flanged bearing for radial and axial loads

0.0015 to 0.003 in., which can be taken into account in machining. A water rinse, or better, neutralization with an alkaline solution such as soda ash, followed by a hot water rinse and immersion in a good oil at approximately 220 deg. F. for 20 min., should follow the acid treatment, Chrysler experience shows.

With these possibilities it has proved practical to make available cored and solid bar stock made from powdered metals in popular sizes to meet machine shop requirements.

Allowable Bearing Pressures

Permissible bearing pressure for self-lubricating bearings is said to be the equal of plain bronze installations. However, one supplier points out that "there are so many variables present in the testing or operation of any bearing that definite recommendations regarding loads, speeds, clearances, etc. are impossible. In addition we must consider composition, hardness, and methods of surface finishing of the shafts, methods of lubrication. operating temperatures, etc. So the problem is an extremely complicated one in borderline applications. Usual physical characteristics such as hardness, tensile strength, elongation, etc. do not have the same significance in their interpretation as they have in their application to cast bronze bearings.

Some evidence of the severity of service in which porous bronze bearings have been successful has already been cited from the experience of Chrysler Corporation. One manufacturer sets the safe static load, including shock, at 4,000 lb. per sq. in. and uses the accompanying chart, based on shaft load, speed and diameter to determine suitable bearing pressures. Another manufacturer suggests the use of a formula involving a PV (pressure-speed) factor. The use of a PV factor is of course, only a rough approximation because only two of the many factors involved are taken into account. Such conditions as the effect of housing design on heat dissipation, bad dust conditions, extreme temperatures, and other variables of service must be allowed for. However, one manufacturer has found it safe to recommend a PV factor of 30,000 with a maximum speed of 500 ft. per min. or a maximum load of 1,000 lb. per sq.in. For intermittent or infrequent service where this factor may go as high as 60,000 with a load of 4,000 lb. per sq.in., the drilled type bearing is recommended and additional lubrication is required for continuous service at 400 ft. per min. or more.

Sintered self-lubricating bearings have been used in practically every known industry. The engineering department, Johnson Bronze Co., lists the following bearings of this type used on automobiles: water pump, brake and clutch pedals, clutch pilot shaft, distributor, windshield wipers, generator, heater, and starting motor. Many are used on all kinds of household appliances. Others are used on conveyors, business machines, electric motors, electric fans, automobile accessories, textile machinery, food machinery, machine tools, portable tools, and in many other special applications.

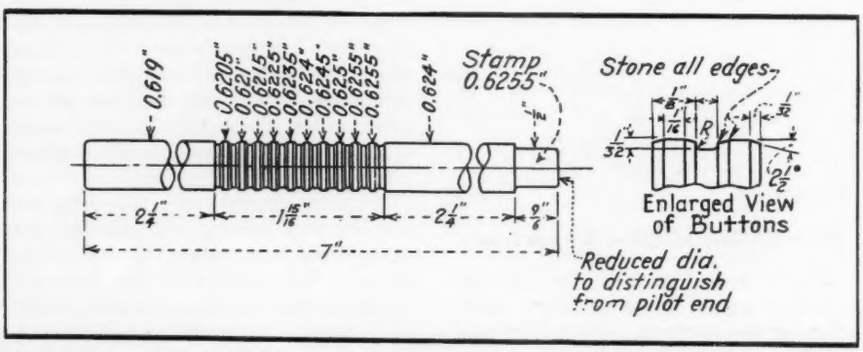


Fig. 2—A typical burnishing tool for porous bronze bearings has buttons whose diameters increase by 0.0005 to 0.001 in. to enlarge the bore

Service Determines Lubrication

Lubricant recommendations vary with the service in which a bearing is placed. For general purpose applications, self-lubricating bearings are impregnated with a good grade of S.A.E. 20-30 oil having a low Conradson carbon. For operating temperatures above 175 deg. F. up to 250 deg., special lubricants are selected to suit the particular application. How long the oil will last in a sintered bearing is dependent upon such factors as the degree of porosity, operating temperatures, and wall thickness of the bearing. Normally these bearings are not used at high temperatures since oxidation of lubricant is not only detrimental to lubrication as in most bearings but also closes the pores of the bearing and destroys its self-lubricating

properties. Also, since copper has a catalytic effect upon the oxidation of oil which is aggravated by elevated temperature and the extensive surface contact provided by the capillaries in the bearing, oils highly resistant to oxidation have been found to be preferable to those which oxidize and leave a lacquer-like residue. Manufacturers recognize this characteristic of copper and one points out that "one great advantage gained by the use of the pure iron bearing is the total absence of the catalytic effect of copper in the oxidation of hot oil so noticeable in copper composition bearings." However, it is also pointed out that millions of bearings have been in long service without experiencing this difficulty.

The materials from which the porous bearings are made vary somewhat with the manufacturer. In general a manufacturer standardizes on an alloy which has shown high qualifications but can readily vary the composition if customers make their own specifications. Bronzes have proved particularly desirable as bearing materials. One maker of these bearings has standardized on 90 percent copper and 10 percent tin. A small amount of graphite is added which serves as a die lubricant, produces a desirable type of porosity, acts as a lubricant and gives the bearing some of its non-seizing characteristics. Johnson Bronze Company has standardized on a bearing containing 83-85 percent copper, 9.5-10.5 percent tin, 4-6 percent lead, and 1.5 percent graphite. The addition of the lead is said to eliminate the harshness of the bronze and prevent galling on to a shaft and cutting it. This company points out that 95 percent of the cast bronze bearing alloys contain up to 10 percent lead. The value of the lead content is said to be shown by a lowering of operating temperatures in comparable bearing applications.

Most producers of sintered bronze bearings caution against applications where there is considerable shock or impact. The method of installing the bearing whereby alignment can be accomplished because of the relative softness of the metal also suggests caution. However, it is pointed by Johnson Bronze Company that "In this connection it is well to remember that applications requiring as much as 400 lb. per sq.in. constant load are rare indeed. . . . The porosity of any sintered bearing affects the load carrying capacity. For example a heavy load requires greater strength, thus limiting the porosity. When the load is light the porosity, and naturally the oil content, can be increased—up to 35 percent by volume. . . . The compression strength of any alloy is comparable to its density." In many instances operating conditions can be improved by design. Improvement in balance on a shaft is effective in reducing shock and impact loading.

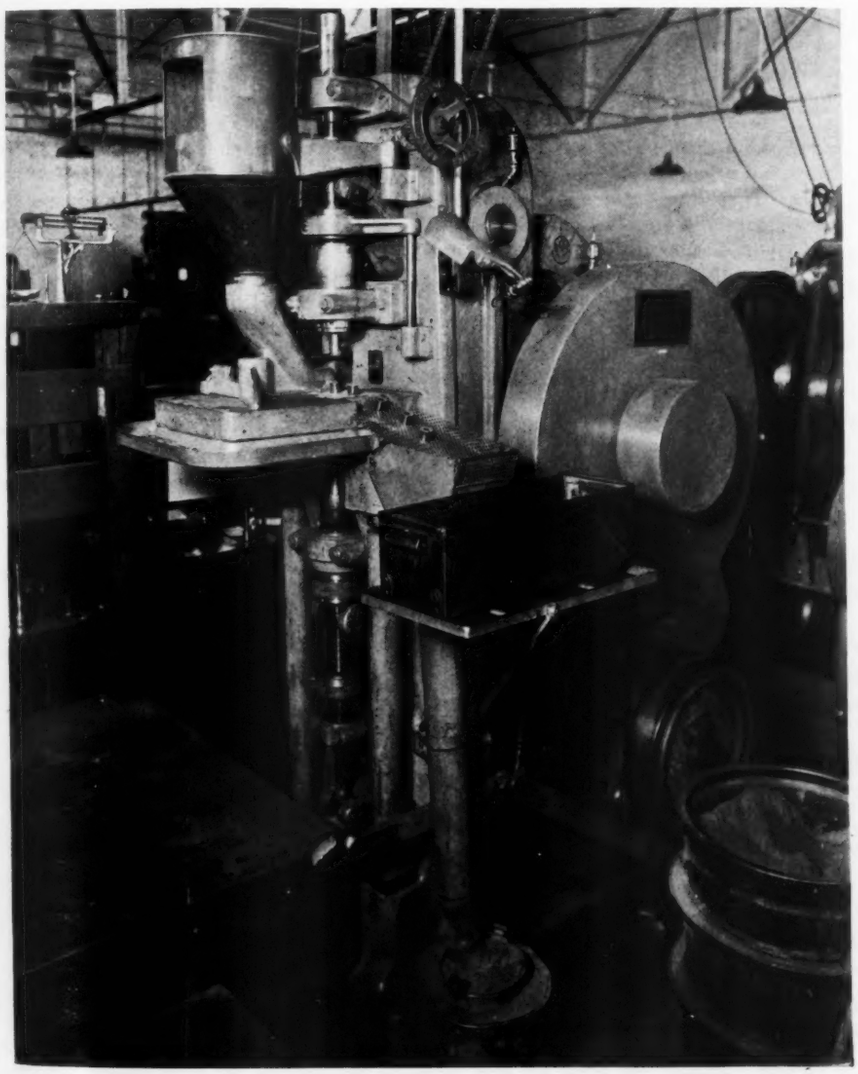


Fig. 4—A briquetting press used by Moraine Products Division of General Motors

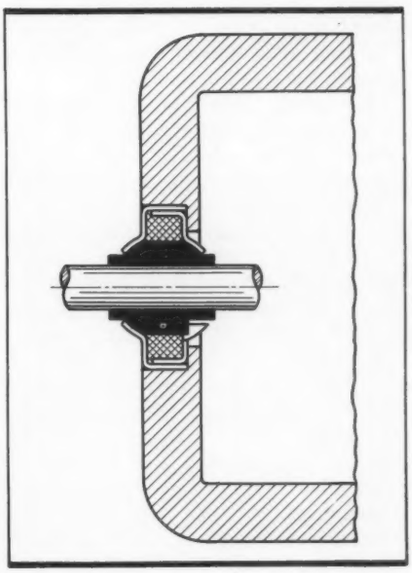


Fig. 5—Self-aligning bearing assembly. The bearing is seated in a two-piece cadmium plated steel shell with an oil saturated felt washer

Chrysler engineers make a point of the hydraulic cushion provided by the capillary structure filled with oil in relation to sustaining severe pressures and shock loads. They also call attention to progress in bearing strength and ductility which tends to eliminate breakage and to materially widen the field of application.

The most common cause for failure of porous bronze bearings in correctly engineered applications is oil oxidation, causing gumming and seizing of the shaft, states the chief engineer of one of the leading producers of these bearings. Oxidation of petroleum oils is purely a

function of pressure, temperature, and time. The catalytic action of free copper, if present, will accelerate this condition.

Pores Not Closed by Wear

Normal bearing wear does not close off the pores of a porous bronze bearing, according to this authority, and confirmed by others. When this condition occurs it can usually be traced back to such things as misalignment, overloads, oil oxidation, incorrect methods used at original installation, which in turn cause a galling or scoring of the bearing surface. Galling and scoring will close off the pores rapidly, just as will incorrect machining. Porous bronze bearings appear to be extremely free from fatigue failures, probably due to the fact that the lack of continuity of the structure greatly reduces internal stress.

Regarding powdered iron bearings, it is generally agreed that they have three important advantages over bronze: (1) greater strength to withstand high bearing pressures, (2) absence of catalytic effect on lubricating oil, and (3) low cost of material. Although they are proving advantageous in an increasing number of applications, it is not now possible to lay down definite recommendations as to their use. However, Moraine Products Division, General Motors Corporation, has found that "where speeds and loads are not excessive (and these values are not yet definitely determined) and with flooded lubrication, powdered iron bearings are recommended, and are proving highly successful."

William G. Calkins, Amplex Division, Chrysler Corporation, states that "powdered iron bearings are much harder and stronger than bronze, and function best under conditions of extreme pressures and low velocities. An outstanding example of this is railroad air brake mechanism where they will far out-perform carburized and hardened steel bushings."

The self-lubrication of powdered iron bearings is not as positive as in bronze bearings and therefore they require generally some provision for lubrication in addition to the lubricant retained in the capillary passages in the metal. More rigid specifications for bearing alignment than for powdered bronze are generally required also.

There have also been experiments in combining iron with copper. One company reports no advantages gained over pure iron while another has gone ahead in the manufacture of a powdered iron bearing containing 5 to 25 percent copper for certain types of service. These bearings are made in varying density, strength, ductility, and hardness to suit the application.

Thousands of Sizes Available

Available sizes of sleeve type self-lubricating bearings which are stocked or for which dies have been made, total close to 1,000 for one manufacturer. Of this total about 75 sizes are stocked by this company. Another company has close to 850 sizes of which 90 are stocked. A third has dies to make 1350 sizes and a fourth can supply over 1550 sizes. These sizes range for the most part from those for $\frac{1}{8}$-in. shafts to those for $3\frac{1}{2}$-in. shafts. However, bearings up to 18 in. diameter have been made in quantity by at least one manufacturer.

Flanged bearings are also available in a wide range of sizes from existing dies. Four manufacturers have die sizes totalling from 125 to 370 each for use on shafts ranging from $\frac{1}{8}$ in. to $3\frac{3}{8}$ in. in diameter. Dies are also available for many sizes of self-aligning bearings, thrust washers, seal rings, and cylindrical splined bearings as well as for a few special shapes. Engineers can use the die list to lower costs by eliminating tool expense. This is especially important where production volume ranges from 1,000 to 50,000 pieces a year. Most orders for less than 1,000 pieces are made in the Hand Production Department of one manufacturer where separate tool equipment is used. Tool charges are said to be low enough generally so that, when amortized over 50,000 pieces or more, the cost is not important.

Costs, of course, are dependent upon many variables such as size and special requirements. These bearings can be obtained not only in odd sizes but in odd shapes and in other alloys when specified; also with closer dimensional tolerances than are standard. Standard pressed powder sleeve bearings for shafts up to $\frac{3}{4}$ in. diameter range for the most part from 10 to 15 cents each in quantities from 75 to 150 and from 40 to 45 cents each when not more than a half dozen are required. A standard sleeve bearing for a 1-in. shaft is 15 to 25 cents each for 75 to 150 bearings or 45 to 50 cents each up to six. A bearing for a 1.5-inch shaft lists at 20 to 30 cents each for 75 to 150 bearings or 50 to 60 cents each up to six. Prices on quantities over 150 are subject to further reductions. In many instances the cost of these bearings is slightly more than that for cast and machined bearings. However, as proof that their cost is competitive with other type bearings the manufacturers point to the fact that the millions of these bearings which have come into use could only have done so with competitive prices, particularly in the case of the automotive industry where so many are used that major companies have plants of their own for making this type bearing.

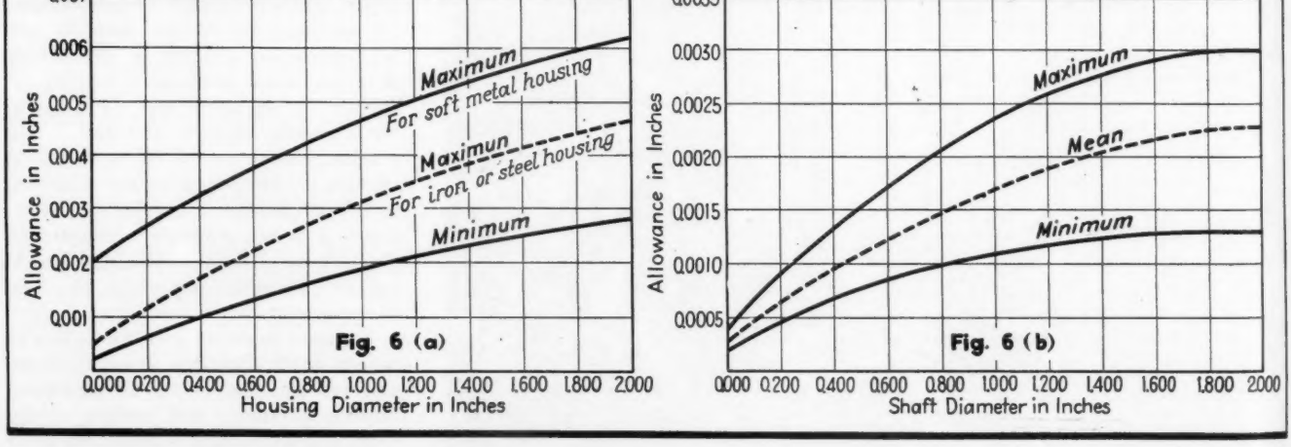


Fig. 6—Allowances recommended by Keystone Carbon Company for press fits into housings and running fits after installation for varying shaft diameter

Question and Comment

Substitute Materials Quest Is Round-Robin; Production Expansion Claimed Only Solution

R. E. BRUCKNER

Possible substitutes for priority materials have been, for the past few weeks, very much the No. 1 item of concern to design engineers. Several meetings have been held all over the country, much newspaper space has been devoted to the subject, and self-appointed authorities everywhere have branded nearly every material as both "strategic" and "plentiful." I have attended several meetings under the auspices of the O.P.M. on the problem of materials substitutions.

This whole question begins to look like the investigation of the Tweed Ring in New York City years ago. The political bosses all lined up in a circle and when asked to point out the guilty party each man pointed to his neighbor so that the investigators simply went around the circle and got nowhere. It appears that every metal suggested as a substitute is in itself either scarce or about to become so.

We have been urged to use plastics for metals; actually, it is practically impossible to place any large orders with the plastics industry which is already swamped. They may even have to curtail their production since many of the materials used in plastics are also used in munitions manufacture. As applied to my own problem of producing intricate precision machinery, the use of plastics is of little promise since they have a tendency to creep slightly and are dimensionally sensitive to temperature and humidity changes.

It is my personal opinion that this whole question of substitution of priority materials reduces itself to a round-robin circus. It is high time that this country realizes that the question of plant expansion must not be determined by sitting back to consider whether the plant can be used after the war is over, but solely by the urgent war-time needs of the country. As far as I can determine, most of the material shortages which now exist are caused by the widespread tendency to believe that the avoidance of idle plants after the war is over is more important than the present defense needs of the country. It is my firm opinion that we should build new plants wherever needed as fast as we can build them regardless of whether or not they will be idle after the war is over.

In other words, the only intelligent attack on this priority materials problem is to take the bull by the horns and increase plant capacity as fast as possible. Our present policy of fighting government demands for plant increases and scurrying around in useless search for substitute materials may prove fatal.

Credit Is Due Where Credit Is Due

To the Editor:

We have noted with interest the splendid presentation "Designs for Applying Press-Fit Seal Units" appearing in the July 1941 number of PRODUCT ENGINEERING, prepared from the sketches submitted to you by us.

However, the writer is somewhat chagrined to see that his name appears with the article. As a matter of fact the layouts and copy which we furnished to you were prepared by our Mr. E. P. Stahl. The writer merely served as an intermediary in the matter.

We are sorry that this credit has been given where no credit is due.

—R. J. HINKLE
Garlock Packing Company

One More Step In a Modern Design

To the Editor:

In PRODUCT ENGINEERING for September 1940, pages 404–406, there is an interesting article entitled "Steps in a Modern Design," by John C. Fagan of Proctor Electric Company. The "modern design" referred to in the article was the "Never-Lift" electric iron, and many of the earlier stages of the design

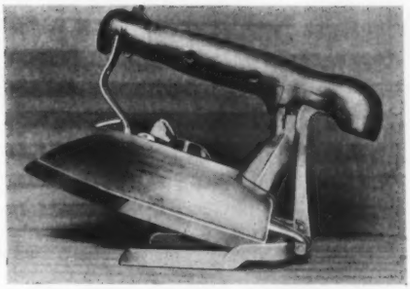


Fig. 1—Early working model of the Never-Lift electric iron had a wooden handle supported by metal brackets

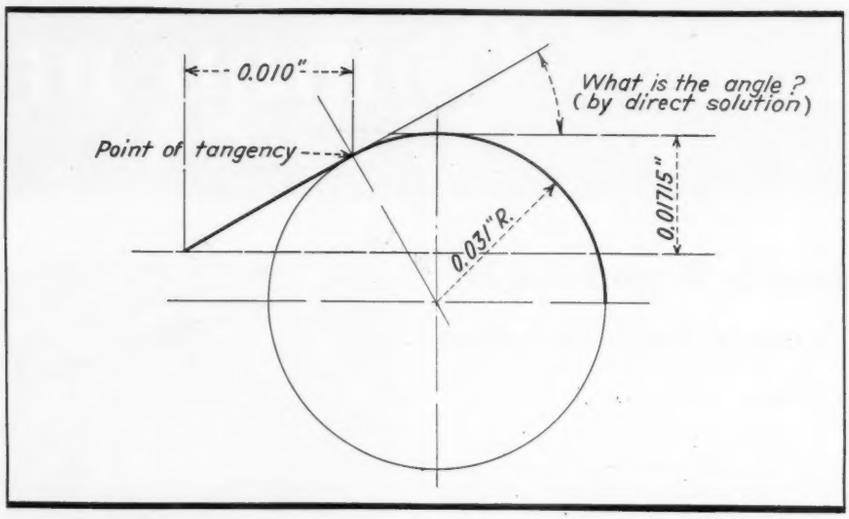
Fig. 2—The 1941 Never-Lift iron can be used as electric or steam iron, has restyled handle with headlight

of this iron were illustrated in the article.

Another step has just been taken in the design of this still-young and increasingly popular iron. As shown in the photograph herewith, the 1941 model has a headlight socket, reflector and wiring molded as integral parts of the Bakelite heat-resistant handle. The new iron also carries a cord support that consists of a 9-in. piece of chromium-plated rod extending out of the iron cover just under the supply cord. This support, which swivels at the base, has a phenolic molded ring cemented to its end so as to permit the user to remove the support when desired.

In addition, the 1941 model is equipped for use with a steam attachment. The steam is piped to the iron from a separate steam generator.

—DON MASSON
Bakelite Corporation



Trigonometric Problem

To the Editor:

Here is a trigonometric problem I came across the other day. The known dimensions are indicated on the drawing. The problem, as noted on the drawing, is to find the angle between the tangent and the horizontal. I have arrived at a solution by the trial and error method, but would like to know if there is a direct method. If any of your readers can find a direct solution to the problem, will you please publish it?

—RALPH CORNELIUS
Cleveland, Ohio

Wanted: A Sprayed-On Sound-Deadening Material

To the Editor:

We are confronted with a problem which involves finding the proper sound-deadening material. According to our specifications, this material is to be sprayed on certain parts of steel cabinets. These cabinets have drawer heads made of double wall construction, and the interior of these drawer heads contains this sound-deadening material.

In finishing these cabinets a vapor degreasing cleaning operation is used. Most of the suppliers of sound-deadening materials which can be applied in the manner described tell us that trichlorethylene will affect their binder. They also tell us that their binder is affected by high temperatures. The exterior of the cabinets will be finished with a high-heat baked enamel.

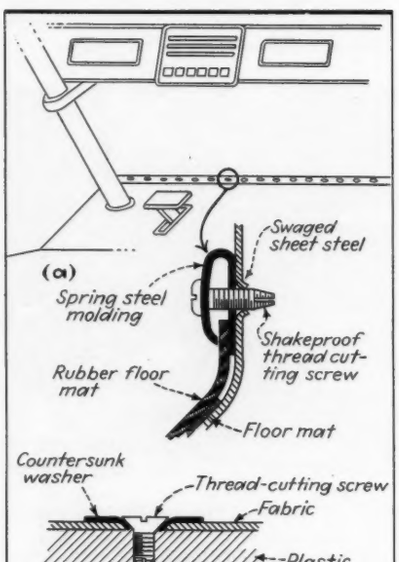
Do you know of any sound deadening material that will meet our needs?

—F. A. GORSHI
Hamilton Manufacturing Co.

Problem of Spur Gears With Varying Centers

To the Editor:

There is a little problem concerning involute spur-gears that, so far as I know, has received no attention in technical literature. Perhaps some of your



Self-Tapping Screws Used For Fastening Fabrics

To the Editor:

In addition to the methods shown in your article "Fastenings for Flexible Sheet Materials" (P.E. June, 1941, p. 316–317), thread-cutting screws are frequently used for fastening sheet rubber and fabrics. Sketch (a) herewith shows how a rubber mat in an automobile is fastened with a strip metal molding. Rubber and metal strip are fastened to the floor sheet simultaneously by thread-cutting screws as shown. Sketch (b) indicates the use of thread-cutting screws with a common countersunk washer for fastening fabric to plastic. The holes for the screws can be either molded or drilled.

—K. C. MACKAY
Shakeproof Lock Washer Company

Can You Work This One?

H. E. SMITH

This month's problem—

Teller's Mistake

A man cashes a check, and by mistake the teller gives him as many cents as the check calls for dollars and as many dollars as the check calls for cents. He later spends $1.93 of the money and then finds that he has two times as much money left as his check originally called for. What was the amount of the check?

Solution to August problem—

Royal Descendants

An elderly queen, her daughter and little son, each weighing 195 lb., 105 lb., and 90 lb., respectively, were kept prisoners at the top of a high tower. The only communication with the ground was a rope passing over a pulley with a basket at each end. The royal prisoners managed to descend in the baskets as follows, using the 75-lb. cannon-ball they found in the tower: The boy descended first, using the cannon-ball as a counterpoise. The queen and her daughter then took the cannon-ball out of the upper basket, and the daughter descended, the boy acting as a counterpoise. The cannon-ball was then allowed to run down alone. When it reached the ground, the daughter got into the basket along with the cannon-ball, and their joint weight acted as a counterpoise while the queen descended. The princess got out, and the cannon-ball was sent down alone. The boy then went down, the cannon-ball ascending. The daughter removed the cannon-ball and went down with her brother ascending. The latter then put the cannon-ball in the basket, let it descend alone, and then descended in the empty basket with the ball as a counterpoise.

readers might be interested in solving it.

Problem—The center-distance of two involute spur-gears varies continuously in obedience to any law whatever between certain limits while the mechanism functions; if the driving gear turns with constant angular speed, does the angular speed of the driven gear vary? If it does vary, (1) derive a formula by which the variation may be calculated. (2) determine whether or not there is a path along which the center can be moved in varying the center-distance to produce no variation in speed.

That this question is of considerable practical interest is evident because there are many applications of spur-gear drives in which the center-distance has to vary while the drive functions.

—PROFESSOR W. H. RASCHE
Virginia Polytechnic Institute

Case Histories in Patent Law

H. A. TOULMIN, JR.

NO. 24

QUESTION: What is patent infringement procedure?

ANSWER: After a suit has been filed in the United States Court for a patent infringement, the defendant files an answer in which it sets up the defenses of prior patents, prior publications and prior public use and sale. Such anticipatory matter is found as a result of searches in the Patent Office records, the literature of the industry and among other manufacturers who may have practiced prior uses.

In order to prove the existence of such prior uses, it is necessary to call witnesses having knowledge of the facts whose testimony must be supported by dated records, drawings, and where possible, photographs or the production of the actual prior use apparatus itself? This proof must be beyond a reasonable doubt, i.e., it must be of the same quality of proof that is necessary to convict a defendant of murder. Such a strenuous rule of proof to defeat a patent requires the utmost care in preparing and presenting the evidence.

The prior use does not need to be a commercial success. If it discloses the invention even though the early use of the idea turned out disastrously commercially, it is still a good prior use proof and will defeat a patent. On this subject Mr. Justice Stone in the noted Smith Incubator Case said as to the Hastings prior use:

"Petitioner urges, and we have considered, numerous other objections to the sufficiency of proof of the Hastings prior use. The only one calling for any comment is the suggestion that the Brooklyn and Muskogee enterprises were not commercially successful. Commercial success may turn the scale when invention is in doubt . . . and the want of it may in some circumstances be evidence of want of operative success. But here Hastings by the use of a method which we have sustained as an invention . . . has attained the particular results described by the patent. He knew the method and used it in a device capable of employing it. In such circumstances want of commercial success, which the record suggests may have been due to lack of technical and business skill, is not an indication that there was no prior use."

Prior use proof must be clear, definite and specific. It must, above all, be truthful and inherently probable because the Judge has the right to discard the testimony no matter how effective nor how many witnesses may have testified, if he is not convinced it is true. This has often happened.

In the famous Barbed Wire Patent Case, in which there were some twenty-four witnesses, 143 U. S. 275, the Supreme Court stated:

". . . We have now to deal with certain unpatented devices, claimed to be complete anticipations of this patent, the existence and use of which are proven only by oral testimony. In view of the unsatisfactory character of such testimony, arising from the forgetfulness of witnesses, their liability to mistakes, their proneness to recollect things as the party calling them would have them recollect them, aside from the temptation to actual perjury, courts have not only imposed upon defendants the burden of proving such devices, but have required that the proof shall be clear, satisfactory and beyond a reasonable doubt. Witnesses whose memories are prodded by the eagerness of interested parties to elicit testimony favorable to themselves are not usually to be depended upon for accurate information."

The patents and publications are offered in evidence without elaborate proof. The proof of circulation of the publications and their date of publication is sufficient to establish the existence of the publication in the trade, but such patents or publications must, in themselves, within their four corners, be sufficient to constitute an anticipation. You cannot read into them by experimental work, or otherwise, what they do not show on their face. As was said in Badische v. Kalle (C.C.A. 2), 104 F. 802, Judge Lacombe stated:

". . . The 'description in a printed publication' of the statute is to be found within the four corners of such printed publication. Judge Coxe tersely and accurately expresses the law and the reason for it in the following passage:

'The question is, what does the prior publication say? Not what it might have said, or what it should have said. If prior patents and publications can be reconstructed by extrinsic evidence to fit the exigencies of the case, the inquiry will no longer be confined to what the publication communicates to the public, but it will be transferred to an endeavor to ascertain what its author intended to communicate' ".

Then too, the patents and publications cannot be combined in order to make out anticipation by showing one part of the invention in one patent and another part in another patent.

In Bates v. Coe, 98 U. S. 31, the Supreme Court established the doctrine that:

"Where the thing patented is an entirety, consisting of a single device or combination of old elements, incapable of division or separate use, the respondent cannot escape the charge of infringement by alleging or proving that a part of the entire thing is found in one prior patent or printed publication or machine, and another part in another prior exhibit, and still another part in a third one, and from the three or any greater number of such exhibits draw the conclusion that the patentee is not the original and first inventor of the patented improvement."

In Hoeltke v. Kemp (C.C.A. 4), 80 F. (2d) 912, it was stated by the Court that:

"Defendant has cited 33 patents as basis for its contention that complainant's invention is lacking in novelty; and this in itself is some evidence of the weakness of the contention. . . . While each of the devices which complainant uses is to be found in one or more of the patents cited, none of these patents covers any such combination as the automatic safety fire check which complainant has evolved. . . ."

News and Summaries

Bausch & Lomb and National Defense

BLAZING HEADLINES in the newspapers of the country early in 1940 imbedded in the minds of the public the mistaken belief that Germany "controlled," had access to, or perhaps even "owned" production facilities of military optical instruments for the United States Army and Navy. This was the imaginative interpretation the press erroneously gave to charges made at that time by the Anti-Trust Division of the Department of Justice against Bausch & Lomb and Zeiss—charges to the effect that these two companies were conspiring to suppress competition by dividing the world into exclusive territories.

In spite of settlement of these charges by common consent, the feeling still seems to persist in some quarters that the Fifth Column had come dangerously near to throttling our source of essential optical instruments.

True, Bausch & Lomb had, in 1921, entered into a contract with Zeiss, but the whole truth of the matter is that our Army and Navy benefited by it because details of advanced German instruments were thus made accessible. Also, B. & L. had notified Zeiss that the contract was suspended as soon as the war came to Europe. Certain items in the contract actually had become void shortly after Nazi control over Zeiss began to be felt.

First relations between Bausch & Lomb and Zeiss started when young American-born Edward Bausch, son of the founder, traveled to Europe to learn European techniques, and returned with licenses to make products in the U. S. based upon research by Prof. Ernst Abbe of Zeiss. Later, Zeiss sent a representative from Jena to see about setting up a factory here to make Military apparatus. So impressed was he with Bausch & Lomb's techniques, that he decided it was better to hook up with them. So, in 1907, Zeiss bought a one-fifth interest in B. & L., the latter company producing Zeiss equipment.

During World War I, B. & L. filled military orders for the Allies. When Zeiss protested this, the American concern felt it best to sever relations, so immediately bought back all the stock held by Zeiss.

The next agreement was entered into shortly after the war when Zeiss, in order to keep their war-torn organization together, agreed to supply designs and samples of their most advanced military instruments to Bausch & Lomb and to the U. S. Government. The contract gave B. & L. a license to make equipment under Zeiss patents, and called for royalty payments to Zeiss. The terms of the contract limited the agreement to the U. S., the only territory in which B. & L. was interested. If Bausch and Lomb should be offered contracts on military optical instruments outside of the U. S., Zeiss was to be consulted.

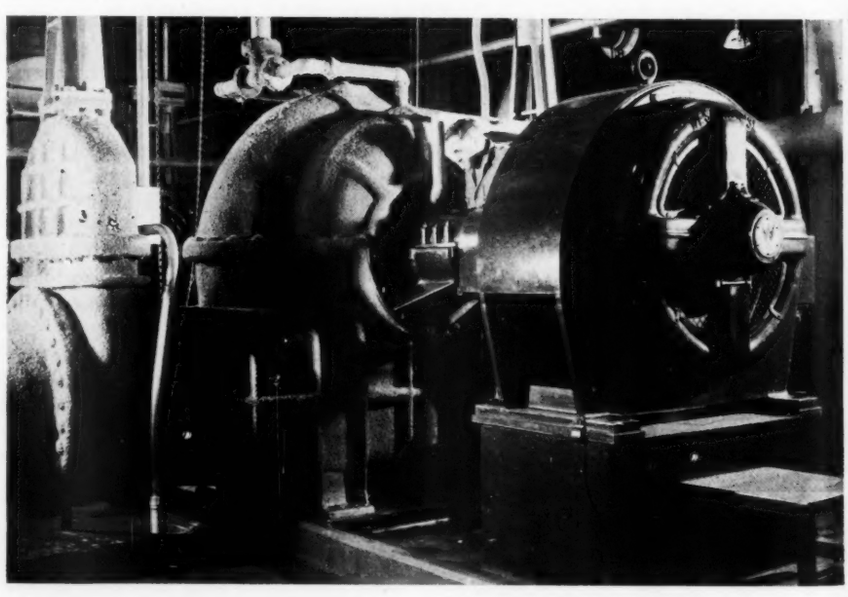
This latter clause was eliminated in 1926 when it was discovered to be a violation of the Sherman Act. The revised contract was filed with the Department of Justice in 1929. In 1937 a copy was filed with the S.E.C.; this was the copy that was discovered by the Department of Justice in 1939 when it was seeking "background" for indictments.

In 1938, Bausch & Lomb accused Zeiss of having made no worthwhile contribution on their contract for 5 years, and shortly thereafter suspended royalty payments and rendered the contract inoperative. It was on this already abandoned contract that the restraint of trade charges were based.

The character and service record of Bausch & Lomb, well known to and often commended by the Army and Navy, has never been well publicized. But it is to the efforts of this company that the United States owes its self-sufficiency in military optical instruments and optical glass. It is not surprising that the Bausch & Lomb Optical Company has just been awarded the Flag of the Bureau of Ordnance of the Navy Department in recognition of outstanding performance in our National Defense Program.

Battelle Institute Builds 35,000-sq. ft. Addition

A FOURTH major building expansion program in recent years is under way at Battelle Memorial Institute, Columbus, Ohio, where a $160,000 addition to the process metallurgy laboratory building is under construction. Additional space demands of enlarged re-



Sweating of the cool surface of this circulating water pump is prevented by insulating the pump and valve with a coating of cork particles and rubber cement. Recently installed in the Toronto Station of Ohio Edison, this pump is driven by a 200-hp., 360-r.p.m., 2,300-volt Westinghouse induction motor.

search programs concerned with the study of chemical and metallurgical processes on a pilot-plant scale will be provided for when the structure is completed. Office-laboratory facilities are planned for 50 additional research engineers and technicians.

Silver Research Throws Light on Substitute Uses

SILVER OR SILVER PLATING may well be substituted for aluminum foil, for nickel as an undercoating in chromium plating, for tin in lead solders, for tin in containers, and to reduce the tin content in corrosion-proof tubes, according to the research progress report just issued by the American Silver Producers.

Where sheet or foil aluminum is required for its corrosion resistance or reflectivity, silver plating on available metals can be substituted. In chromium plating, experiments are now under way to determine what the advantages are of a corrosion-resistant, silver base for wear-resistant chromium. It is hoped that aluminum and nickel can be replaced in part by silver in such parts as refrigerator shelves, ice cube trays, toasters, and others.

Tests made on extruded tubing made from a 3.5 percent silver—96.5 percent tin alloy have shown a bursting strength of 2,500 lb. per sq. in.—almost double that of pure tin. Tests on threaded joints showed that the alloy had 25 percent greater tensile strength than joints made with pure tin tubing. This may make feasable threaded connections in distilled water lines.

Silver-lined cans for packaging chemicals are now in development, and containers with silver coatings have also been packed with different commoditiess. Results from service tests have been varied, and at the present time it has not been determined why some container linings are satisfactory, and others contaminate the products. For the general run of containers, the advantages of silver do not warrant the extra cost, but for packaging some specialized products, silver is the most desirable container lining.

Parts and Supplies Given Defense Rating

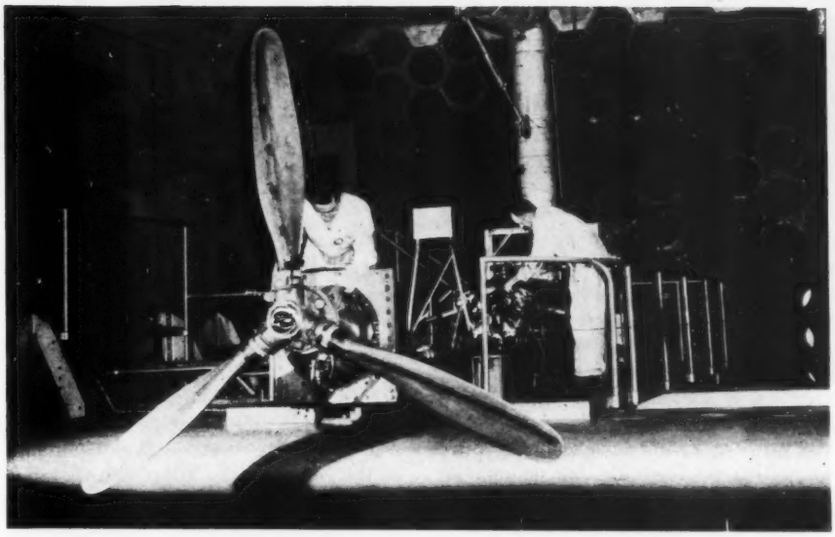
REALIZING that the flow of tools, supplies and equipment, which every plant must have in order to maintain production, is threatened unless producers of such items are given priority for raw materials, the Priorities Division has established the Defense Supplies Rating Plan. This plan sets up a priority for future business on the basis of past business, and requires manufacturers of these items to show evidence that their products are used for defense. This, in turn, calls for complete cooperation of the user.

Manufacturers granted use of the plan will determine the percentage of their total production that goes into defense channels and will then be given an A-10 rating on that part of their materials requirements. These percentage figures will be determined from information secured from customers, who will be asked:

(1) To identify orders for items that will be used for defense work.

(2) To furnish a monthly notarized affidavit stating the percent of defense sales to total sales made by the customer.

These requests are being made now, and this activity has been gaining momentum during the last two months. Ratings are being issued as fast as the supplies manufacturers can complete their data, but it is believed that this is not fast enough to avoid difficulty. Chief cause for delay is lack of cooperation of the customers, some of whom take the typical attitude: "I've had no trouble yet, and will do something about it at the first sign of trouble." This attitude, according to O.P.M., fails to recognize that this class of supplies and parts must be made well in advance and kept in stock until required.



Hydraulic airplane propeller of a new type, shown here set up for vibration tests, is now going into production in the big new plant of General Motors' Aeroproducts Division near Dayton, Ohio. With these propellers, engine speeds are held constant. To meet variations in load requirements, blade angles are automatically changed by a centrifugally operated mechanism within the hub. Blades are of hollow, heat-treated gear steel, and are surprisingly light. Propellers in all types and sizes for Allison engines have been designed and are in test. Propellers for 2,000-hp. are in development.

Do You Know That—

SYNTHETIC RUBBER can be sprayed on metal and other materials by a new process which sprays powdered material through a gas flame. The synthetic rubber fuses into a smooth continuous film on the metal. (54)

THE 82-TON DOUGLAS B-19 BOMBER is the first airplane with engines totalling 8,000 hp. Four engines in a Pan American Clipper total 6,400 hp., and twelve engines in the famous Dornier DO-X totalled 7,200 hp. (55)

RECORDING INSTRUMENT CHARTS, made in three eye-ease colors of plastic, can be wiped clean and re-used. Average life is two years. (56)

SAFETY GOGGLES are now available with lenses ground to prescription to correct defective vision. (57)

TAPERED ROLLER BEARINGS are replacing babbitted thrust bearings on marine propeller shafts because of increased thrust loads set up by modern high-powered diesel engines. (58)

DEFENSE PROBLEMS keep two-thirds of the research staff busy in one leading electrical manufacturing company. The laboratory's own machine shop is working 56 hr. a week—90 percent on war work. (59)

ENGINEERING IN WASHINGTON

McGRAW-HILL WASHINGTON BUREAU, *PAUL WOOTON, CHIEF*

Seen in a shipyard, by PRODUCT ENGINEERING'S Washington writer on an inspection trip: torch men cut holes and bevels in plate steel almost as smooth as it can be done with tools; an all-welded ship looking modern and clean as a bombshell. A British vessel in for repairs after caving its stem in a convoy collision. The hole, big enough to throw an automobile through, had been filled with concrete, and the ship made three or four more Atlantic crossings. Shipbuilder had to send for the duPont boys to blast the concrete out.

Floating oil tanks, capable of being floated down rivers and towed across the ocean, have been proposed to the Government by Earle P. Halliburton, industrialist of Oklahoma. The size suggested is 100,000 barrels. Halliburton said that large vessels could tow a string of them. In his opinion the tanks could be built at the rate of one every four days. It was unofficially reported that Washington engineers were much interested.

Styles, sizes and models of all manner of things are moving toward standardization and simplification. If the war goes on the "alikeness" of products will go to limits now unthought of. During the World War the defense authorities had figured out standard garments for men and women and if peace hadn't come, America would have been in coveralls or whatever it was. Donald Nelson, O.P.M. chief of purchases, said recently that a Washington bureau soon would be set up to handle standardization, materials substitutes, etc. In the past, 125 sizes of wheelbarrows were reduced to 41; 8,000 sizes and varieties of abrasive paper were cut to 2,000; 386 kinds of forgehammers were trimmed to 180; 5,000 varieties of spades and shovels were boiled down to 1,000. Even these records could be drastically outdone.

Voltage reaching spark plugs can be told at a glance by the pilot of military planes. Bureau of Standards developed the device for Navy, in an effort to find better, more dependable plugs. Most plugs used in American aircraft engines are mica, although great interest is shown recently in porcelain plugs. When mica plugs reach a very high temperature, they may become conductors, and short their spark gaps. Also, under some conditions, lead from the gasoline works into the leaves of mica and the plug becomes a conductor. Different types of plugs are required for different aircraft engines. For instance, a plug that gave maximum performance in the British Rolls-Royce engine failed to work in a similar American engine. The Bureau has been working on the problem for months and will continue.

Information in Washington is more than a little confusing. Here are two examples of what a writer is up against. One day recently an expert in glass manufacturing told us that "bullet proof" glass in military planes is ¾ in. thick; that it will stop .30-cal. bullets, but cannot be depended upon to stop .50's. Then immediately a science writer tells us that the glass is three inches thick and it will stop .50's at close range, hitting at right angles. Another time an airplane builder, selling fighter planes to Britain, told us the British are moss-backs, and that they stick to .30-cal. machine guns, ignoring the new 20-mm. and 37-mm. shell guns, one hit from which can demolish a plane. In three days comes a report from Britain that the new Beaufort fighter is bristling with 20-mm. shell guns. To speak mildly, it's exasperating.

Dr. Vannevar Bush, president of the Carnegie Institution of Washington, until recently chairman of the National Defense Research Committee, and chairman of the National Advisory Committee for Aeronautics, is now director of the new Office of Emergency Management, created by executive order of the President. This office will serve as liaison between all government research agencies. Dr. Bush said that he will depend heavily upon the old research groups, particularly upon the National Academy of Sciences and the National Research Council. The aim, of course, is to develop new weapons and defense equipment as rapidly as possible.

Vapor lock tends to develop in aircraft engines when they are climbing steeply to high altitudes, particularly during hot weather. Tests by the Services and air operators show that the pump in the fuel system causes the gasoline to boil, which generates the vapor. The Bureau of Standards has worked out information which is making possible the design of fuel systems that in large measure eliminate the boiling of fuel. A second pump is placed in such a position that the fuel is moved with the least possible suction. Large and better-placed fuel lines also help. Every valve and fitting was analyzed and found to have an individual resistance to the flow of fuel and vapor. The vapor problem is not yet completely solved, but more dependable performance of airplane fuel systems is already achieved.

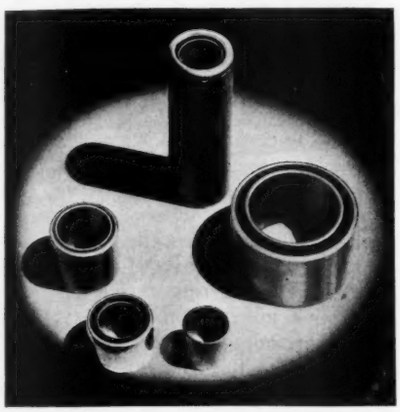
Army will adopt carbines, replacing nearly all of the .45-cal. pistols now in use. Seven models, six by commercial manufacturers and one by Ordnance, have been tested. All but two have been eliminated. One of the remaining two is really a little Garand, the Army's new semi-automatic. Both guns will be carried in field tests and subjected to all sorts of abuses. The carbine will be 8 in. shorter than the Garand or Springfield, and about 4 lb. lighter. It will use .30-cal. ammunition which is not, however, interchangeable with regular rifle ammunition. Its feed will be clips of two sizes: one holding ten rounds and the other 20. Overall length; 36 in.; barrel, 18 in.; weight, 5 lb.; type, semi-automatic, gas-operated. Carbines are intended for men whose duties prohibit carrying regular rifles, and will increase the number of rifles in a regiment of infantry about 50 percent.

Soybean protein, to replace casein for defense adhesives, is being expanded by Department of Agriculture chemists. Because casein is a milk derivative its production is limited, and is progressively more limited as demand for edible milk for health building and lend-lease export increases. It is estimated that 10,000 tons of soybean protein will be required annually to make up for casein shortages. This is three or four times present production. Soybean protein can be substituted for casein, with only small differences, for paper coatings, plywoods, plastics, water paints, paper sizing, leather finishes, and insect sprays.

New Materials and Parts

Torflex Bearings With Bronze on Steel Bushings

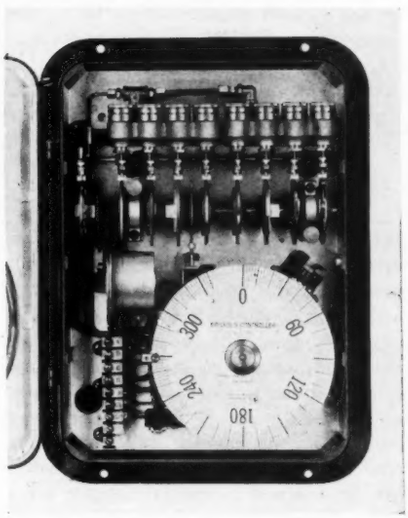
Recommended for application where the Torflex construction is required to fit into a smaller space, new bearings are now being made with inner walls



of a new, thinner material of either plain or graphited bronze on steel. Increased resistance to pounding and shock, a low coefficient of friction, and a wider range of sizes and shapes are features. The increased shock resistance, together with the Torflex backing, permit the combination to be used where excessively high impact and shock are present, and where cast bronze bearing material alone would not stand up. The rubber wall surrounding the center inner wall section can be made in almost any thickness necessary to handle radial loads, or to compensate for misalignment, to stop vibration and transmission of noise, and for similar requirements. Harris Products Co., 5408 Commonwealth Ave., Detroit, Mich.

Time Cycle Controller

Designed for use on tire molds and other plant operations where a number of factors must be accurately timed according to a fixed program, the new model A-118 impulse-sequence cycle controller actuates or engages the necessary mechanical, electrical or pneumatic devices for automatically carrying out the intended schedule. Time measurements and pilot valve operations are handled by separate mechanisms. Separation of these two functions gives accurate timing of the factors under control, high speed and torque for pilot valve operation, and flexibility of application. Timing is accomplished by a Telechron-driven aluminum disk on which is printed a 25-in. time scale. The desired schedule of operations is punched with an ordinary ticket punch on the time scale. The location of these holes determines the time of operation of the cam mechanism. The cams are individually adjustable and their setting does not require fine adjustment. The Bristol Co., Waterbury, Conn.



Rubber Base Paint

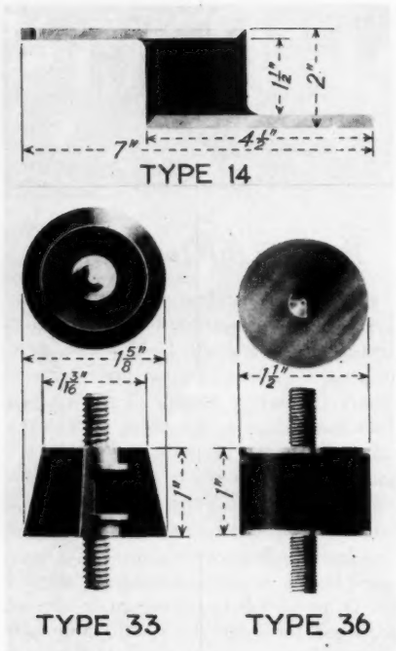
Paratex metal coating, a chlorinated rubber base metal coating, is especially adapted to all types of exposed iron and steel, and can also be applied to protect aluminum, copper and galvanized metals. The coating is resistant to acids, alkali, fumes and chemicals. Paratex paint uses only pigments which are inhibitive or neutral to steel corrosion. Paratex primer is reinforced with rust-inhibitive elements so as to provide maximum rust protection. The primer, when applied over scales of rust and paint that do not have true adhesion to the surface, is found to penetrate and work its way laterally under those scales and turn up the edges to view. This shows up the defects of a priming job at once, rather than months later. Available in standard size containers and in standard colors. Truscon Laboratories, Detroit, Mich.

Dust Tight Interrupter

Circuits in outdoor, damp, wet, or dusty locations can safely be disconnected or interrupted by this new non-automatic inclosed De-ion circuit interrupter. A closely machined fit between the handle shaft and bushing with heavy rubber gaskets between the inclosure and cover make them water-tight. Inclosures (NEMA Types 4 and 5), are furnished in either cast aluminum or cast iron, both of which have an aluminized finish. A high interrupting capacity is provided to interrupt a circuit adjusted for 5,000 to 10,000 amp. depending upon frame size. De-ion arc quenchers confine, divide and extinguish arcs almost instantly as the contacts open, thus prolonging contact life. Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Vibration Insulators

To decrease vibration and noise in mounting machinery of many types, three new Vibro-Insulators are now available. Type I-4 is recommended for a load in vertical shear of 80 lb. per sq. in., deflection in shear of 1 in., at a loading of 80 lb., and a minimum disturbing frequency at this deflection of 470 per min. This type can also be sup-



plied with the rubber in compression. In Type 33, the rubber is applied only in compression with the maximum loading 150 lb., and the deflection at that point 5/32 in. with the minimum disturbing frequency at that deflection 1,200 per min. Type 36, although best adapted for work with the rubber in compression, can also be applied in shear. With 35 and 50 durometer hardness, loading beyond 20 percent of the rubber thickness, or 0.175 in. is not recommended. Under this load the minimum disturbing frequency is 1,250 per min. and the load necessary to deflect the 35 durometer mounting is 100 lb., and for 50 durometer mounting 85 lb. These are maximum load limits with lower loads recommended where possible, especially where the disturbing frequencies are greater than 1,250. B. F. Goodrich Co., Akron, Ohio.

Thermostat

This slow make and break thermostat was designed for applications where an inexpensive small thermostat is required to control temperatures. It is claimed to be ideally suited for use as an over- or under-temperature cut-out Construction is sturdy and compact.

Contacts are large, silver-to-silver. The thermostat can be built for a wide range of temperature settings and various operating combinations. It will handle loads up to 1,000 watts and voltages up to 120 volts a.c., 60 cycles. Curtis Development & Mfg. Co., 3266 N. 33rd St., Milwaukee, Wis.

Immersion Tin Finish

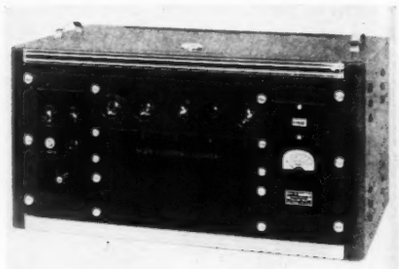
Bon White, a new immersion tin finish applicable to all copper and brass surfaces, can be applied in 10 sec. and can, in many instances, replace slow boiling methods of tin plating. The solution is prepared by dissolving 16 oz. of sodium cyanide and 6 oz. of Bon White paste in 1 gal. of boiling water. When cooled to room temperature, no further heat is necessary and no adjustment is required. Enamel and glass containers are used and the work can be handled in baskets or on wire. The inexpensive, highly effective white finish, being pure tin, has considerable tarnish resistance. Alrose Chemical Co., Providence, R. I.

Precision Switch

Requiring a minimum of change in operating pressure to produce a direct positive make and break, this snap-action precision switch operates on a new principle with a wide variety of modifications adapting it for many uses. Long service under continuous operations and resistance to wear are other outstanding characteristics. Friction is almost totally eliminated. The switch can be adapted to special shapes, sizes and positions, or built into almost any style mechanism. It is single pole and is furnished with normally open, normally closed or double throw contact arrangements. Pressure is from ½ oz. to 14 oz. Weight is less than 1 oz. Available in three standard models: 10 amp., 115 volts a.c.; 5 amp., 250 volts a.c.; and 3 amp., 450 volts a.c. Acro Electric Co., 3176 Fulton Rd., Cleveland, Ohio.

Electronic Counter

This high-speed electronic counter is capable of counting from 0 to 2,000 counts per min., regardless of the rate or variations of the flow of the objects to be counted. The counter input circuit (two conductors) is connected to a single throw, single pole switch which is actuated by the moving objects being counted. The high-speed counting is made possible by using a number of gas-triodes. The usual set-up is to have a cycle of 5—numbered 1, 2, 3, 4 and 0.



Each count is picked up by a gas-triode in the order stated. Every time No. 0 is fired the registering device is moved up another unit, and then the cycle of firing the other gas-triodes is repeated. At the end of the run, the total count is obtained by multiplying the figures indicated on the register by 5, and adding the serial number of the gas-triode lighted. Shallcross Mfg. Co., Collindale, Pa.

Precision Switch

A cast metal housing for installation in conduit wiring systems is now available for the Type D Mu-Switch. For industrial and machine tool applications, the housing is of bronze with hub

tapped for ½-in. pipe thread; for aircraft application, an aluminum case is used with male ¾-in.—20 thread; others to specification. Access to the large binding screw terminals of this 2-kw. precision switch is provided by a readily removable base with two mounting holes on 1½ in. centers. An important feature of the conduit style is its built-in, blow out magnet which quickly quenches the d.c. arc, thus pro-

longing contact life and obviating need for condensers. Available with compression plunger over-travel mechanism capable of absorbing ⅛ over-travel, with leaf spring, roller, or short-travel plunger. Mu-Switch Corp., Canton, Mass.

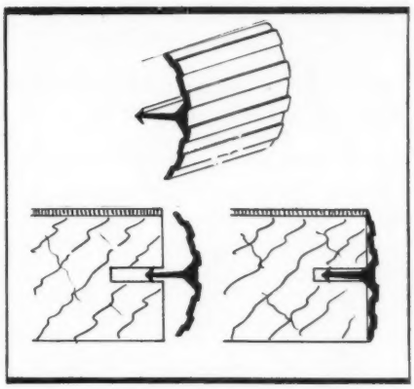
Rubber Micrometer

Soft or compressible materials can be measured in thickness with the Carson Rubber Micrometer to the same degree of precision obtained with precision measuring instruments on steel parts. The Carson Rubber Micrometer consists of a precision micrometer head fitted with a large diameter dial and mounted in a rigid instrument frame. When the micrometer tip is brought into contact with a metallic rider resting upon the work, exact instant of contact is indicated by a green light before any pressure is exerted on the piece being measured. This is made possible by a special electronic circuit operating on a new "currentless contact" principle sensitive to displacements as small as five millionths of an inch. The instrument is available with a variety of special fittings and attachments for

specific measuring problems on such materials as rubber, paper, plastics, cork, fibre, leather, felt, insulated wire and textiles. Instrument Specialties Co., Inc., 240 Bergen Blvd., Little Falls, N. J.

Plastic Molding

A new design of extruded plastic molding has a "T" shape with a small barb on the flanged portion of the strip. When this arrow portion of the strip is forced into a groove cut in wood, soft plastic or similar material, it "bites" into the wood and holds the molding in place. The curve of the "T" tends to pull the inserted part out of the wood, thus increasing the grip of the plastic. Made of Tenite, this new "Interlox" extruded molding is available in two widths and many colors. The molding can be punched, nailed, stamped,



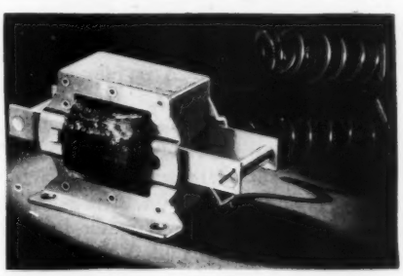
drilled, or sawed without chipping or cracking. The resilience of the plastic and its unique shape allows the trim to be formed with ease around corners. Extruded Plastics, Inc., Naugatuck, Conn.

Ink for Marking Vinyl-Acetate Sheets

An ink that can be furnished in any standard color, silver, gold, black, white, blue, red and other colors, successfully marks or prints on vinyl-acetate plastic sheets. It is compounded in a paste form and used as a regular printing ink. By spreading on a flat plate or platen it can be applied by rubber stamp or metal die. The new ink penetrates the vinyl-acetate surface; color content adheres under rigid tests such as rubbing, weather tests, salt water tests and all natural conditions. The Acromark Corporation, 251-257 N. Broad St., Elizabeth, N. J.

Solenoid for Machine Tools

An improved solenoid designed primarily for machine tools cannot be harmed by oil or coolant; the cloth-taped coil is impregnated with oil-resistant and water-resistant varnish. The improved construction is more rigid, with integral feet and side plates, and with more and heavier rivets. The pull exerted by the PA-3945-C solenoid plunger at 110 volts ranges from a maximum of 23 lb. at zero stroke to 5 lb. when the plunger is extended 1 in. Corresponding current flowing in the



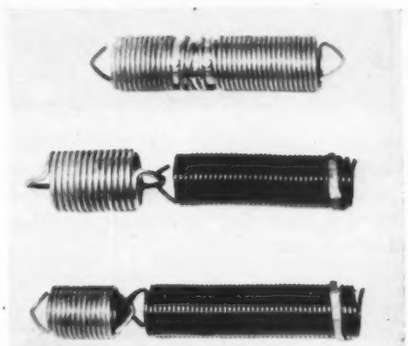
solenoid at 110 volts for corresponding strokes and pulls ranges from 0.76 amp. at zero stroke to about 5 amp. at 1 in. To avoid over-heating, the solenoid should be used so that any current flow in excess of the minimum is momentary only. John S. Barnes Corp., 301 So. Water St., Rockford, Ill.

Varnish-Saturated Tubing

A new line of varnish-saturated tubing for increasing dielectric strength of insulated wires when used as leads, connecting wires, or for insulating bare wires, is made of closely woven cotton yarns thoroughly impregnated with insulating varnishes. The varnishes penetrate all through the tubing rather than forming veneer laminations on the surface. The tubings have an exceptionally high factor of flexibility and dielectric strength combined with low moisture absorption. Three grades are available, in sizes 20 to minus 1½, either black or yellow. Appliance and Merchandise Dept., General Electric Co., Bridgeport, Conn.

Self-Compensating Springs

Utilizing the property of a 36-percent nickel steel to become stiffer as the temperature increases, a new spring now available can be combined with under-

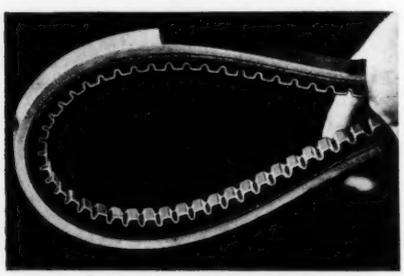


correcting springs where high accuracy is required. While the ordinary steel or alloy spring becomes approximately 2 percent more resilient for every increase of 100 deg. F. in temperature, it is claimed that these new self-compensating springs can be held constant within these limits to 0.02 percent. These springs are now being used in spring scales, aeronautical instruments and other spring-actuated instruments which must be used in localities where they are exposed to a wide variation in temperature. In two bottom springs illustrated, the shorter section is the over-correcting section. The first spring is a combination of 36-percent nickel

steel and steel. In the second spring, the correct deflection ratio has been maintained, but the coil length has been varied to compensate for zero error. In the third spring, shown at the top, which is made of 36 percent nickel steel and beryllium copper, not only the calibration but also a final temperature adjustment can be made. All-Weather Springs, 72 Washington St., New York, N. Y.

Cog V-Belt

Because of its new type of cog construction on the inner surface of the belt, the Dayton Cog-Belt can be used on either flat or V-pulleys. Not only does this construction provide greater flexibility and longer belt life, when flexing around small pulley diameters, but for V-flat drives it applies the scientific principle of increasing traction by means of a non-skid design. The patented cog construction provides greater grip and less slip on smooth flat pulley surfaces. Likewise, when riding in grooved pulleys, this new belt provides a greater gripping power with die-cut raw edge sides which present the same undistorted driving surface to the pulley regardless of side wear. The new belt is



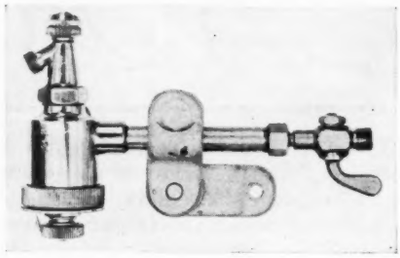
being manufactured in all standard lengths in A, B, C, D and E cross-sections, and in matched sets for multiple drive service. Dayton Rubber Mfg. Co., Dayton, Ohio.

Alkaline Copper Plating

Significant as a plating finish for replacing nickel heretofore used in plating and now unavailable because of national defense, a new Unichrome Alkaline Copper plating process has been announced. With this time and labor-saving process, smooth, fine grained deposits can be plated to thicknesses of 0.001 in. or more. It buffs easily with minimum pressure, and is often used without buffing prior to bright nickel plating. No special cleaning or activation is required for subsequent plating. The plating bath operates at moderate temperatures, is non-corrosive, and easy to control. United Chromium, Inc., 51 E. 42nd St., New York, N. Y.

Spray Lubricator For Graphite Lubricants

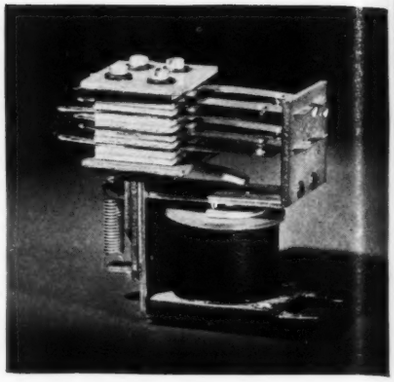
Lubricants containing dispersions of colloidal graphite can now be sprayed on bearing surfaces automatically with these automatic spray type lubricating devices. The sprayers are mounted with a universal mounting, making it possible to adjust the lubricator to any de-



sired position or angle, thus insuring uniform coverage. Spraying action can be started and stopped instantaneously by air-operated pistons, providing accurate regulation of the amount of colloidal graphite lubricant supplied. Intermittent operation as high as 150 shots per min. can be obtained. The automatic air brushes are available in any one of three sizes of fluid assemblies for light, average or fast application, and with various sizes of multiple heads. Heads are adustable for fan or cone spray, permitting adaptation of the spray gun to any of the carriers, such as oil, water, kerosene, carbon tetrachloride. Paasche Air Brush Co., 1909 Diversey Parkway, Chicago, Ill.

Cellular Rubber

New insulation boards, designated U.S. Royal, are made of a new cellular rubber which has a high insulation value and is twice as light as cork. The material consists of a thin external dense layer inclosing microscopic cells of nitrogen gas in a matrix of rubber. The "K" insulation value (b.t.u. per hr. per deg. F. temperature difference for a specimen 1 ft. sq. and 1 in. thick) of cellular rubber is expressed as 0.237. This figure compares with 0.30 for regranulated cork, 0.34 for gypsum in powdered form, 0.39 for laminated fiber board, and 0.59 for cellular dry gypsum. Other specific properties are moisture resistance, oil, acid and fire resistance, rot proof, structural strength, long life, resistance to vermin and termites, and good workability. Unusual structural strength is claimed. The board can easily be cut to shape with a bandsaw or powersaw, and surfacing can be done with a planer. The material is thermoplastic. United States Rubber Co., 1230 - 6th Ave., New York, N. Y.

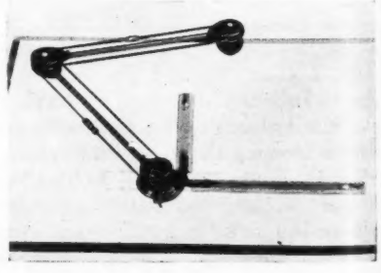


Relay

New Type F relay is claimed to be unusually compact and capable of giving long uninterrupted service. The contacts have self-cleaning, wiping action, with heavy contact pressure. It is available with 1, 2, 3 or 4 poles; either single throw or double throw, to operate on a.c., or d.c. Measurements of the Type F relay are: 2¼ in. high, 2½ in. long and 1⅛ in. wide. G-M Laboratories, Inc., Chicago, Ill.

Drafting Machine

True Line drafting machine, embodying protractor, vernier, T-square, scales and triangles, is easily and conveniently operated and eliminates smudging and blurring caused by moving instruments over the drawing. The machines are equipped with "Quick Flick" controls. A flick of the thumb from its natural position and the scales are released for 15-deg. automatic stops, or for intermediate stops and locking. Again, a flick of the thumb and the scale can be set at any angle with a protractor and vernier reading of zero-to-zero. No adding and subtracting is required when engrossed in detail around a focal point. Design permits the use of the instrument with the elbow to the left or right. Protractor can be used at any angle in the complete circle, making accessible the total area of the board. All parts subject to wear are of hardened steel; the index plate is notched so that it will take up any wear automatically. Frederick Post Co., Hamlin & Avondale Aves., Chicago, Ill.

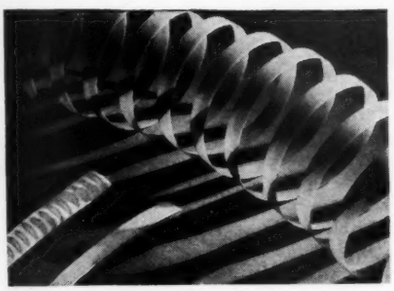


Ameripol-Coated Fabrics

Fabrics coated with Ameripol, the recently introduced synthetic rubber, have just been announced in standard widths ranging from 35 to 49 in., and approximate weight per lineal yard ranging from 0.595 to 3.62 lb. Among principal applications of the Ameripol synthetic rubber-coated fabrics are in diaphragm service in gas meters and regulators, or in fuel pumps handling oil, high test gasoline, alcohol, or other liquids which are detrimental to natural rubber. Balloon cloth is used for the lighter gage fabrics and lightweight ducks and sheeting for the heavier thicknesses, which range from 0.008 to 0.0050 in. B. F. Goodrich Co., Akron, Ohio.

Extruded Plastics

Extruded plastic, especially suitable for decorating plastic products, automobile decorations, electrical appliances, lighting fixtures, novelties and many other industrial and consumer uses, is now available in continuous lengths. It can be made in almost any design, with or without fastening channels, or in tubing or strip. Available in all colors or translucent. Mack Molding Co., 150 Main St., Wayne, N. J.



Electro-Blackening Process

Almost all metals, including aluminum, steel, stainless steel, zinc, cadmium, nickel, silver, gold, lead and tin, can be electrolytically blackened with a new process called Electro-Ebonol. The process is claimed to be particularly important because of the shortage of nickel salts for black nickel solutions. Current densities required for the process are low, ranging from ½ to 5 amp. per sq.ft. Voltage ranges from 1 to 2 volts, depending upon the set-up. Anodes can be made of carbon or of stainless steel. Tanks can be made of wood, stainless steel, ceramic ware or monel metal. The black coating is deposited very rapidly, taking from only 30 sec. to 3 min., depending upon current density. The Enthone Co., 440 Elm St., New Haven, Conn.

Manufacturers' Publications

AVAILABLE PROMPTLY UPON REQUEST ADDRESSED DIRECTLY TO THE MANUFACTURER

Materials

BELTING—The B. F. Goodrich Co., Akron, Ohio. Catalog Section 2140, 8 pages, 8½x11 in. Discusses construction, advantages, splicing methods and minimum pulley diameters for Multicord belting.

CERAMIC COMPOSITIONS—American Lava Corp., Chattanooga, Tenn. Engineering Data and Property Chart 416, 11¾x21 in. unfolded. Properties of ceramic insulating materials, of considerable value to the design engineer, are set forth in tables and graphs on this wall chart.

CHAIN—F. G. Taylor Chain Co., Hammond, Ind. Catalog, 28 pages, 8½x11 in. Illustrates and describes many types and grades of chain, including sling and crane chains, BBB c il chain, high carbon electric weld loading chain, log chain.

INSULATING MATERIALS—General Electric Co., Bridgeport, Conn. Catalog 55-102, 60 pages, 8x10½ in. Lists prices, and describes hundreds of items including varnished cloth, varnishes, Glyptals, tapes, cords, sleeves, tubings, mica materials, wedges, and soldering materials.

PORCELAIN—Lapp Insulator Co., Le Roy, N. Y. Bulletin 196, 197 and 198, total 16 pages, 8½x11 in. Describes Lapp chemical porcelain for chemical-resistant mechanical and chemical equipment.

Mechanical Parts

CLUTCHES—The Carlyle Johnson Machine Co., Manchester, Conn. Bulletin Series 2, 12 pages, 8¼x9 in. Illustrates and describes with engineering drawings the single and double type of floating plate multiple disk Maxitorq clutches.

COUPLED REDUCTION GEARS—Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa. Booklet B-2278, 8 pages, 8½x11 in. Describes coupled reduction gears for driving compressors, line shafts, generators, and similar equipment. Cross-section drawings marked with arrows show position of important parts and give physical dimensions.

PLASTIC GEARS—Synthane Corp., Oaks, Pa. Folder, 4 pages, 8½x11 in. Principal properties of Synthane silent stabilized gear materials are set forth. For ease in calculating horsepower transmissible by Synthane gears, six charts are included.

POROUS BEARINGS—Keystone Carbon Co., 1935 State St., St. Marys, Pa. Catalog Listing 1941, 24 pages, 8½x11 in. Describes properties and uses of complete line of "Selflube" porous bearings, and furnishes complete details on the correct method of installation. The last two pages contain graphs showing the allowance for press fit into housing, and for running fit after installation.

SPEED NUTS—Tinnerman Products, Inc., 2038-2046 Fulton Rd., Cleveland, Ohio. Engineering Standards Catalog 123-3, 9¼x11½ in. This well-prepared catalog includes engineering drawings, dimensions and materials listings for the complete line of Tinnerman Speed Nuts and Speed Clips. Of particular value to design engineers, the catalog is full of sketches showing typical applications of all these different types of fastenings.

TORFLEX BEARINGS—Harris Products Co., 5428 Commonwealth Ave., Detroit, Mich. Bulletin 128-20, 8 pages, 8½x11 in. Covering stock sizes of Torflex flexible bearings, data include the radial loads, radial and axial deflections, rubber wall thicknesses, etc., of sizes available from ⅛ to 5 in. dia. Also shows are typical applications.

VALVES—Reading-Pratt & Cady Div., American Chain & Cable Co., Reading, Pa. Bulletin illustrates and describes Union Bonnet Bronze Globe and Angle Valves, and covers new improvements.

WIRE ROPE — Hazard Wire Rope Div., American Chain & Cable Co. Inc., Wilkes-Barre, Pa. "Safe Use of Wire Rope," 24 pages, 6¼x7 in. Comprehensive booklet gives tables of breaking strength for commonly used wire rope constructions, together with safety factors. It also offers constructive information on factors affecting the safe life of wire rope.

Electrical Parts

MARINE ELECTRIC COUPLINGS—Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa. Folder F-8635, 6 pages, 8½x11 in. Electric couplings for transmitting engine torque to the gear in diesel powered units between 500 and 5,000 hp. are described.

MOTORS—The Dumore Co., 14th and Racine Sts., Racine, Wis. "The Adventures of Jimmy Dumore," 28 pages, 10¼x10¼ in. This cartoon-illustrated, nicely bound booklet gives an interesting and comprehensive presentation of the field for applications of Dumore fractional horsepower motors.

SWITCHES—Automatic Switch Co., 41 E. 11th St., New York, N. Y. Catalog, 82 pages, 9x11½ in. This complete catalog of electrically operated switches illustrates and sets forth specifications for automatic transfer switches, remote control switches, contactors, relays, control panels, and solenoids. To help design engineers, the catalog includes description of the operating principles, construction details and control circuit data.

Books and Bulletins

Engineering Drawing

D. E. HOBART—*699 illustrations, 430 pages, 6½x9½ in. Blue clothboard covers. Published by D. C. Heath and Co., 285 Columbus Ave., Boston, Mass. Price $2.75.*

Here is an engineering drawing textbook that is intended to be informative and to stimulate interest rather than to be a source of material for drawing problems. Because the author feels that "time can be spent to advantage in the reading and interpretation of drawings which would be more complicated than could be assigned as drawing problems," he devotes considerable space to drawings of advanced details, and supplements the academic and theoretical aspects with much material on the practices of industry.

The theoretical treatment of the subject is handled in such a way that the reader may need no other help. Although the treatment of orthographic projection is closely tied in with descriptive geometry, the reader could probably grasp both this subject and the chapter on developments and intersections without a formal descriptive geometry course.

The chapter on fastenings, screw threads, piping and springs contains much handbook data, and so does the appendix. The chapters covering structural drafting, including wooden joints, welding, and methods of detailing structural steel beams, girders and columns, are particularly complete.

Mechanics

JOHN W. BRENEMAN—*178 illustrations, 141 pages, 6⅜x9¼ in. Light blue buckram covers. Published by McGraw-Hill Book Co., 330 West 42nd St., New York, N. Y. Price $1.50.*

This volume, one of the "Industrial Series" of texts prepared by members of the staff of the School of Engineering of Pennsylvania State College, is written for industrial training programs, self-learners, and engineers who wish to "brush up" on their knowledge of mechanics. It is easily readable, understandable, and is a comprehensive study of those phases which have fairly direct practical application.

Mr. Breneman has included in his book the treatment of conditions of equilibrium in static structures, a discussion of center of gravity and moment of inertia (without the use of mathematics beyond trigonometry) and dynamics. Unlike many of the texts on this subject, this volume incorporates the study of simple machine gears, gear trains, pulleys and mechanisms.

Strength of Materials

JOHN W. BRENEMAN—*138 illustrations, 145 pages, 6⅜x9¼ in. Light blue buckram covers. Published by McGraw-Hill Book Co., 330 West 42nd St., New York, N. Y. Price $1.50.*

Another of the "Industrial Series" of Pennsylvania State College, this book has been written to meet the needs of industrial training by providing an adequately simplified discussion of the principles involved. The problems supplementing the text have been taken from the fields of practical engineering and include fundamentals of both mechanics and strength of materials.

The book includes the usual topics of tension, compression and shear stresses. Riveted joints are explained in an up-to-date manner, and welded joints are covered. Beam design is thoroughly discussed and beam deflections are considered. The design of steel and timber columns is covered by the latest methods and equations of design. Mathematics above the level of trigonometry have been avoided.

Hydraulic Machinery

E. MOLLOY—*49 illustrations, 96 pages, 5½x8½ in. Blue fabricoid covers. Published by Chemical Publishing Co., Inc., 234 King St., Brooklyn, N. Y. Price $2.*

Written in a descriptive style, this book gives a brief overall survey of the field of hydraulic machinery as used for shaping metal, with a few references to plastics. Designs and practice used to supplement the contents are British. The elementary principles of hydraulic operation are set forth in a few pages, this is followed by a description of the construction of rams, cylinders and press parts. Various types of forging presses for shaping metal are described, as well as presses used in the manufacture of guns, projectiles and armor plate. The book also shows the construction of special forging presses used in railroad shops, and for other work.

Nickel Alloy Steels

Five data book inserts, each 6¼x8¾ in. Published by International Nickel Co. Inc., 67 Wall St., New York, N. Y.

These five revised sections to International Nickel Company's data book "Nickel Alloy Steels" cover Structural Nickel Alloy Steels, Nickel in Nitriding Steels, Properties of Nickel Alloy Steels at Low Temperatures, Definitions of Terms Relating to Heat Treatment, and Case Hardening of Nickel Alloy Steels.

The section covering "Properties and Applications of Quenched and Tempered Nickel Alloy Steels" is also being brought up to date.

Stainless Steels

32 pages, 8½x11 in. Published by Allegheny Ludlum Steel Corp., Pittsburgh, Pa. Available free.

This bulletin, one of two prepared by Allegheny Ludlum for use in defense courses, is an excellent and quite complete elementary discussion of stainless steel. The first chapter gives a general description, explaining the effects of alloy additions to steel. Chapter II tabulates corrosion-resistance of stainless steels to a list of about 250 corrosive agents. The remainder of the bulletin covers all methods of fabrication, giving much detailed technical information.

Aluminum in Aircraft

104 pages, 33 tables, 35 illustrations, 5½x8¼ in. Published by Aluminum Company of America, Pittsburgh, Pa. Available free.

Intended primarily for the newcomer who wants to obtain a general picture of the use of aluminum in aircraft, this well illustrated booklet contains much technical information covering alloys, heat treatment, corrosion resistance, shapes and fabrication methods. One chapter of particular interest to design engineers covers the choice of materials and processes.

Supplementing the general discussion, 48 pages of tabulated data cover general information, mechanical properties, commercial tolerances, sheet sizes, wire, rod and bar sizes, and tubing sizes and shapes.

Another booklet called "Forming Aluminum," published as a companion piece to "Aluminum in Aircraft," gives detailed information on drawing, spinning, and other fabrication methods.

Machine Tool Electrification Forum Proceedings

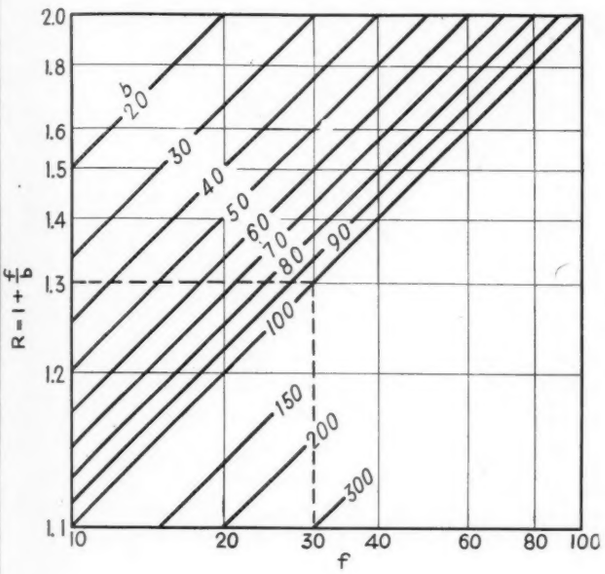
115 pages, 8½x11 in. Brown cardboard cover. Published by Westinghouse Electric & Mfg. Co., E. Pittsburgh, Pa.

This book contains copies of papers presented at the 1941 Machine Tool Electrification Forum, held under the auspices of Westinghouse Electric & Mfg. Co., April 14-16. Every paper in the book is complete with illustrations, charts and graphs, as presented at the Forum. Also included is a roster of attendance. The booklet will be of considerable interest to engineers in the machine tool and related fields. Also recorded are a few pages of pictures illustrating events at the Forum.

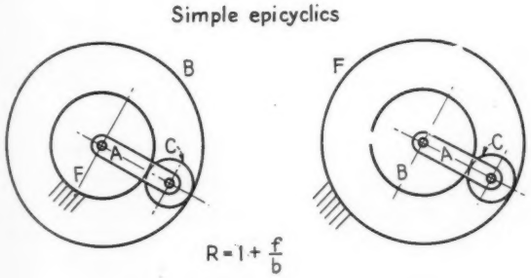
EPICYCLIC GEAR TRAIN RATIOS

H. A. BOLZ
Assistant Professor of Mechanical Engineering
Purdue University

By means of the log-log chart on the following page, the velocity ratio of any epicyclic gear train can be determined if the number of teeth in each gear is known. The chart can also be used to determine the numbers of teeth that will give the desired speed ratio.



Simple epicyclics



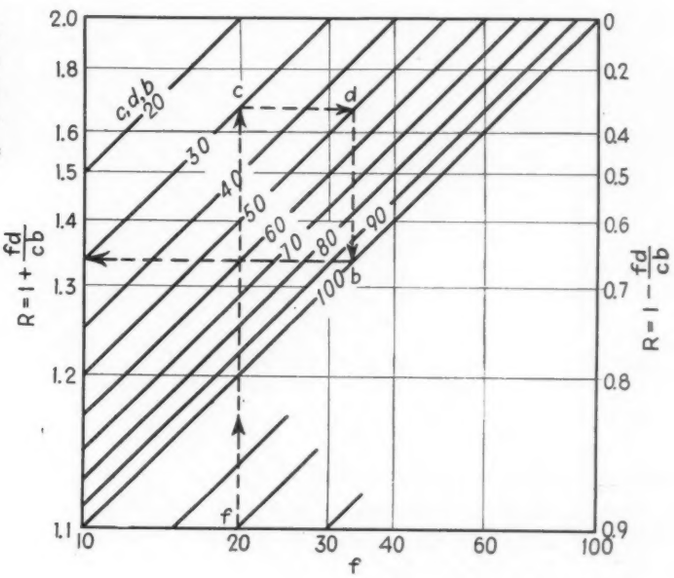
$R = 1 + \frac{f}{b}$

For the two types of simple trains as in the above diagrams, follow according to two trace lines as shown in the miniature diagram above for the following example:

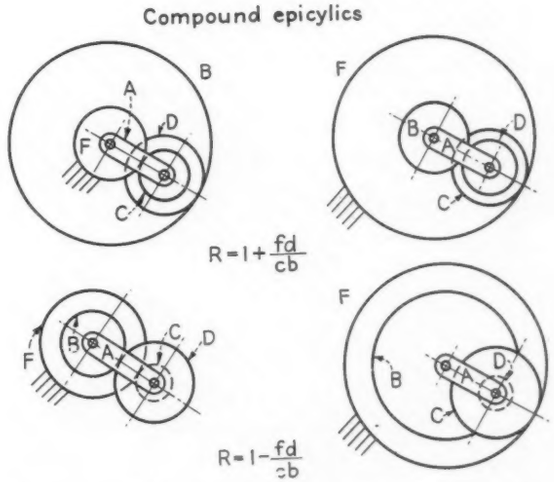
Number of teeth f = 30
Number of teeth b = 100

If on the chart on the next page, lines are traced as indicated on the miniature diagram above, it will be found that R, the speed ratio, is 1.30. Checking R by calculation,

$$R = 1 + \frac{f}{b} = 1.30$$



Compound epicylics



For compound epicyclic trains as in the above diagrams, four trace lines must be connected in the same order as that in which the gears make contact. For the example shown:

f = 20 teeth in fixed gear F
c = 30 teeth in gear C
d = 50 teeth in gear D
b = 100 teeth in gear B

Order of contact is *f-c-d-b* or *b-d-c-f*.
As per chart on following page, depending upon type of train

$$R = \frac{\text{r.p.m. Gear } B}{\text{r.p.m. Arm } A} = 1.33 \text{ or } +0.67$$

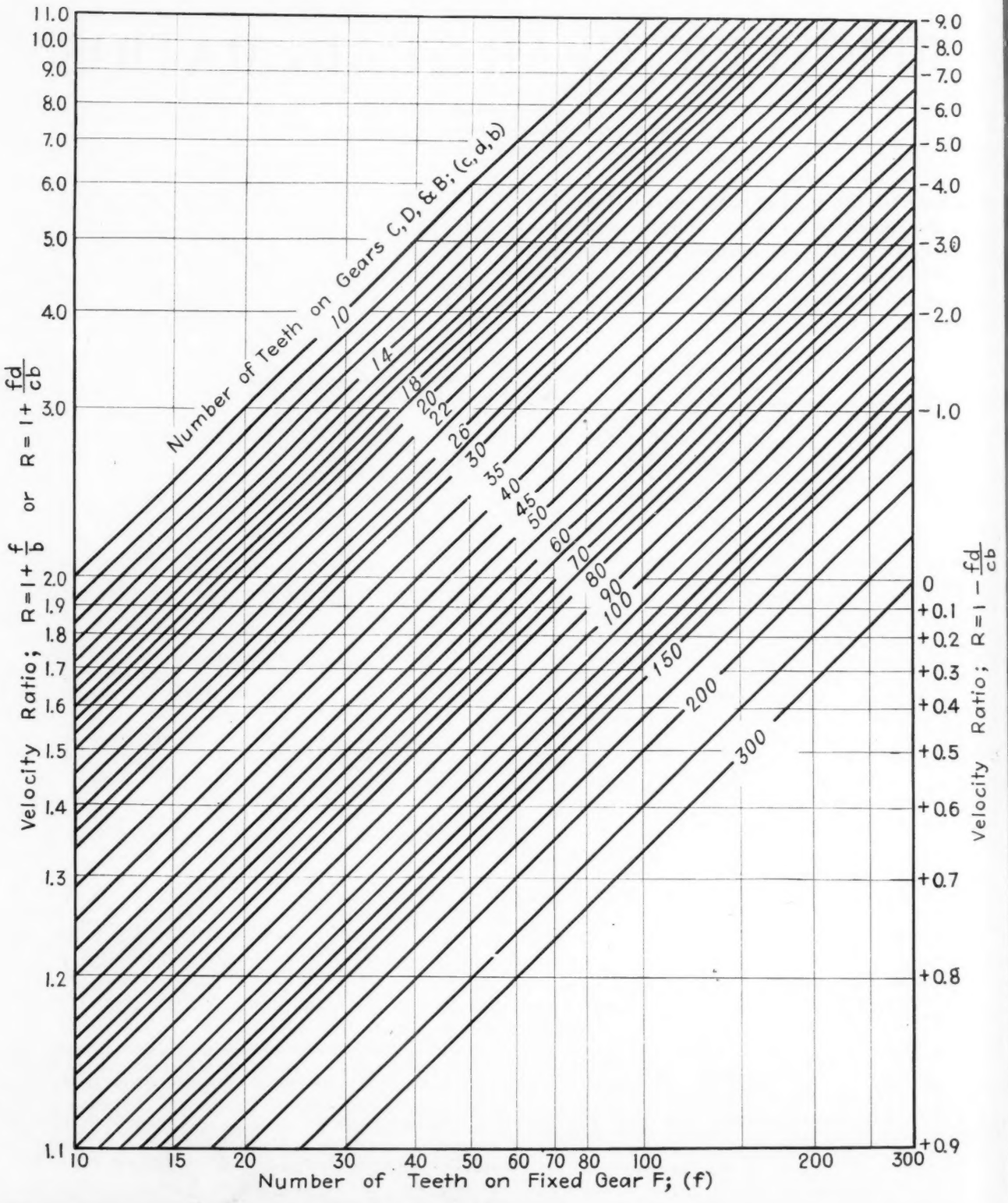
By calculation,

$$R = 1 + \frac{fd}{cb} = 1.33 \text{ or } R = 1 - \frac{fd}{cb} = +0.67$$

EPICYCLIC GEAR TRAIN RATIOS

H. A. BOLZ

Assistant Professor of Mechanical Engineering, Purdue University



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